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A Study of the Inheritance of Skin Color, Total Carotenoid Pigments, Dry Matter, and Techniques in Classifying These Characters in Ipomoea Batatas.

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A STUDY OF THE INHERITANCE OF SKIN COLOR, TOTAL CAROTENOID PIGMENTS, DRY MATTER, AND TECHNIQUES IN CLASSIFYING THESE CHARACTERS IN IPOMOEA BATATAS

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ABSTRACT

Approximately 1500 first year sweet potato seedlings were grown from controlled crosses between breeding parents of known phenotypes. Storage roots of parents used in the study varied in total carotenoid pigments from 0 mg./100 gm. fresh weight to 18 mg./100 gm. fresh weight. The skin color of the roots of the parents used also varied from white to purple.

Storage roots of each seedling population were first classified into visual groups for total pigments, color differences measured by a tristimulus colorimeter and then analyzed for total carotenoid content by a standard quantitative analytical procedure. The percentage dry matter was also determined for roots of each seedling.

White flesh color of storage roots was found to be incompletely dominant over orange flesh (total carotenoid pigments). When a white flesh parent was crossed with an orange flesh parent, storage roots of most of the F_1 seedlings had little or no carotenoid pigments.

When two parents high in total carotenoid pigment content were crossed, a large percentage of the F_1 seedlings produced storage roots having as much or more carotenoid pigments than roots of either parent. However, when a parent high in total carotenoid content was selfed, a fairly large number of white seedlings (low in total carotenoid pigment) segregated. A possible explanation for the large number of white

flesh seedlings segregating from parents with high pigment is the epistatic action of two or more genes for white flesh color over genes for orange flesh, or the presence of an inhibitor gene. The character for orange flesh color (total carotenoid pigments) appear to be controlled by several genes. These genes, possibly 6, are probably additive in effect.

A highly significant positive correlation coefficient existed between quantitative total carotenoid pigment determinations and observed total carotenoid pigments using the visual scale of 0 to 5 for total pigment content. This indicated that the visual scale gave a fairly reliable estimate of the total pigment content of sweet potato roots.

The L and a_L values on the Gardner color difference meter were found to be reliable estimates of the total carotenoid pigments. A weaker association existed between total pigments and b_L values.

The darker the skin color of roots of the parents involved in a cross, the larger was the percentage of the F_1 seedlings with rose or purple skin colored roots. The character for skin color in sweet potatoes is quantitative in nature and controlled by several genes. This indicated the presence of complementary genes (C and R) and possibly the presence of a basic gene (D) for color.

A highly significant positive correlation coefficient existed between skin color of roots and total carotenoid pigments.

In most cases transgressive segregation for inheritance of dry matter occurred in F_1 sweet potato seedlings. There were seedlings in

each progeny that were lower in dry matter and others that were higher in dry matter than either parent. In most cases the mean percentage dry matter of storage roots of the progeny was equal to the mean of the two parents.

A highly significant negative correlation coefficient existed between percentage dry matter and total carotenoid pigments. This indicated that the roots of the seedlings of the progenies high in dry matter generally had a lighter flesh color, and they were very low in total carotenoid pigments. However, varying degrees of association between percentage dry matter and total carotenoid pigments were found among different progenies.

INTRODUCTION

The sweet potato (Ipomoea batatas) is the only representative of the Convolvulaceae family that is of major importance as a food plant. It is recognized as such on every continent that has tropical, sub-tropical, or temperate climate within 50 degrees north or south latitude.

The sweet potato is a native of tropical America and the West Indies, but is now cultivated in many areas of the United States, South America, Africa, Mediterranean Europe, India, Japan, Australia, and New Zealand (35).

In recent years the sweet potato has been one of the most important vegetable crops of this country, exceeded in dollar value only by Irish potatoes, tomatoes and lettuce (5). In the south where it is frequently a staple in the diet, it ranks first among the vegetable crops in total acreage and dollar value. The greatest farm value of the crop in the United States was realized during the war year of 1943, when 71 million bushels harvested from 857,000 acres were valued at $146,000,000 (5).

The outstanding value of the sweet potato as a food has not been appreciated generally. While the sweet potato has been considered mainly as a source of carbohydrate, it is also a valuable source of vitamins, particularly of beta-carotene (pro-vitamin A) in the orange fleshed varieties and of l-ascorbic acid (vitamin C) (5).

Vitamin A activity may be present in a food either as vitamin A itself, or as beta-carotene, a yellow pigment, which is converted into vitamin A by the human body. Carotene is present in large amounts in green leaves of plants, and green and yellow vegetables. Human and animal foods which furnish large amounts of carotene are the sweet potato, carrot, all varieties of leafy vegetables, clover, alfalfa, oats and rye grass. A small amount of carotene is found in yellow corn, but other grains do not contain any of this pro-vitamin (5).

Beta-carotene is the principal yellow pigment found in all sweet potatoes (24). It is this compound that performs many important biological functions which are essential to the good health of both man and animals. The vitamin A requirement of man varies with age and activity (17). On the basis of the carotene content of a good strain of Porto Rico, it has been calculated that if one eats a sweet potato weighing 150 grams two or three times a week, he will obtain all of the vitamin A required for this period.

Since 1937, when Miller (63) at Louisiana State University, found methods for inducing the sweet potato to bloom and set seed, carotene content has served as a basis for a far-reaching program of research on improving the edible quality and nutritional value of the crop through the process of breeding. The parental breeding stocks used so far have been found to be very heterozygous genetically as indicated by segregation in F_1 generation hybrids. The carotene content of sweet potatoes has been materially increased by the process of breeding and selection.

This research was initiated to study the mode of inheritance of flesh and skin color, and dry matter content of F_1 generation hybrids from parental crosses between known phenotypes, and to determine satisfactory techniques in classifying the genetic characters for possible use by plant breeders in the future.

REVIEW OF LITERATURE

Early History

It is generally accepted by most sweet potato authorities that the sweet potato is of Central or South American origin (18, 33, 9, 81). No reference has been found that would indicate that this crop was grown in Europe or Asia prior to its discovery in America by Columbus. However, great use has been made of the sweet potato as a food by Asians and Africans as well as Americans since its introduction into these continents.

At one time, it was believed by some Botanists that the sweet potato was of Asiatic origin. It is now believed that the true yam (Dioscorea) was mistaken for the sweet potato (Ipomoea batatas) in this case.

The acceptance of the sweet potato as of American origin by early workers was difficult because it was known to have reached New Zealand, Tahiti, and the Fiji Islands prior to its discovery in America (18). The natives of these islands named the sweet potato the same as did those of other areas of the world indicating a common original source. In New Zealand there is a legend among the natives that it was first brought to the Island in canoes composed of pieces of wood sewed together (18, 39). Another legend held that the Maoris, upon not finding the sweet potato they prized so highly for food, sent an expedition to bring it back (18).

Among Ipomoea species the sweet potato is the only known hexaploid. Most species are diploids, but a few tetraploids have been found. The chromosome number of several Ipomoea species was reported by King and Bamford (50) in 1937. They concluded that the basic number was 15 with most species being diploid. Ipomoea ramoni was found to be a tetraploid. Ten varieties of Ipomoea batatas examined by King and Bamford had 90 chromosomes in each. Though the exact number was difficult to determine, they listed 90 as the complete set and concluded that Ipomoea batatas was a hexaploid.

Ting and Kehr (101) conducted meiotic studies on two varieties of sweet potatoes in 1953 and found a gametic number of 45 chromosomes. They concluded that Ipomoea batatas was of alloploid origin. The absence of multivalents was taken as evidence against autoploid origin. Secondary association and the unusually high number of chromosomes in the species were both used as evidence of alloploid origin. They advanced the hypothesis that the sweet potato arose from a hybrid between two distinct but related species, one a tetraploid of 2N equals 60 and the other a diploid of 2N equals 30. The sterile hybrid resulting from this cross underwent a natural doubling of the chromosomes and became a fertile 90 chromosome species.

Almost complete failure has resulted from modern attempts to hybridize Ipomoea species. Toutine (104) reported capsules formed from crosses of I. batatas X I. fastigiata, I. batatas X I. macrohyma, and I. batatas X I. pandurata. No further report as to whether these capsules contained viable seed was found.

Montelaro (91) obtained one non-viable seed when I. batatas was crossed onto I. tricolor but obtained no seed from crosses between I. fistulosa and I. aquatica.

Ting (102) attempted to cross I. batatas with 25 other species. Two non-viable seeds were obtained in the cross, I. batatas X I. pescapre. A total of 3,172 inter-specific pollinations were made. Thus, the probability of inter-specific hybridization between I. batatas and other species of Ipomoea seems rather low.

Columbus (35) found the sweet potato a common food item among the Indians of the Carribean Islands and described the roots as resembling carrots with a savor of chestnuts (85). According to several writers (85, 86, 39, 35, 18), Columbus took the sweet potato back to Spain on his fourth voyage.

Hedrick (39) reported that the Spaniards often carried sweet potatoes from America to Spain. Cooley (18), similarly, reported this fact. He also stated that the sweet potato was introduced into Europe 60 years or more before the Irish potato, which unfortunately and erroneously was introduced under the same name. The sweet potato was first known in Spain as batata or padada and from these words came the English word, potato.

Boswell reported that in Japan (14) there are conflicting reports as to the first introduction of the sweet potato into that country. Laufer (54) reported that in 1605 the sweet potato was taken to the Luchu Islands and there saved the people from famine many times. It became second only to rice in value as a food crop. Japanese records

credit the sweet potato alone with saving the country from almost complete famine in 1832, 1844, 1872, and 1896 (58).

Gray (33) stated that the sweet potato was in cultivation in both Florida and South Carolina by the time Jamestown was settled. Bartram (105) observed plantings of sweet potatoes around Indian villages in the south in 1773, and Romans (33) referred to their use by the Indians in Florida in 1775.

Inheritance of Carotene and Other Characters

In their early reports on sweet potatoes, several writers referred to white and yellow fleshed varieties (35, 39). Matlock (60) stated that the predominant pigment in the sweet potato was beta-carotene, with a small amount of Xanthophylls present, one of which was violaxanthin. He reported that the intensity of the flesh color was an indication of the carotene content.

Ezell and Wilcox (24) found that the principal pigment in sweet potato roots was beta-carotene, the precursor of vitamin A. However, the fleshy roots were found to contain appreciable amounts of yellow pigments other than beta-carotene. The carotene/total pigment ratio varied among varieties and within varieties. The ratio increased with an increase in intensity of yellow color. Triumph, a light flesh-colored variety, contained a small amount of carotene shortly after harvest, but the carotene soon disappeared from the roots in storage.

Miller et al. (72) reported a wide range in the beta-carotene content of the roots of different varieties. Of the total pigments in

the roots of the sweet potato, it was found that the principal one was beta-carotene.

Purcell (84) reported in 1962 on carotenoid pigments in raw Goldrush variety roots, in cooked puree, and in precooked dehydrated flakes stored at various temperatures. Seven pigments constituted 98 percent of the total pigments present: phytoene 2.6 percent, phytofluene 0.8 percent, beta-carotene 89.9 percent, zeta-carotene 1.2 percent, beta-carotene-5,8-epoxide 2.5 percent, gamma-carotene 0.7 percent, and hydroxy-zeta carotene 0.5 percent. No alpha-carotene was found. The relative amounts of the different carotenoids did not change appreciably during processing of the sweet potatoes into flakes or during storage of the flakes. Carotenoids apparently were not destroyed during processing.

Of the early reports on sweet potato breeding, Thompson (100) mentioned the production of both white and yellow fleshed seedlings. Stout (98) reported on selections of sweet potato seedlings producing storage roots with bright yellow flesh.

In 1922, Beattie (12) studied several hundred varieties and seedlings for various characters. He found that the intensity of the yellow or salmon flesh color of the root varied among seedlings and varieties. He also found some clones that had a salmon flesh color splashed with reg pigment.

Toutine (104) found seedlings of progenies to be variable in flesh color and in other characters that he studied. Seedlings, resulting from seed of crosses, had hybrid vigor and were heterozygous

for all phenotype characters including flesh color. Miller (64) in 1938 also noted the variability in seedlings produced in Louisiana.

Ezell and Wilcox (26) reported that samples of sweet potato roots taken from different fields varied within a variety as much as 45 percent in total carotenoids and 145 percent in beta-carotene. Sweet potato roots taken from the same field for two seasons contained twice as much carotene one season as the next. Those grown under limited soil moisture were higher in carotene than those grown with abundant moisture. Variation in the carotene content of different roots from the same plant ran as high as 47 percent in Orange Little Stem and 82 percent in Yellow Jersey. High yielding plants within a plot had a significantly higher carotene content than the plot average. They found carotene content to be more closely associated with the rate of root growth than with the size of the roots at harvest.

During the early stages of the sweet potato breeding program in Louisiana, Miller and his colleagues (69) found some seedlings with a higher carotene content than either parent or any known variety. A large number of seedlings were studied from 1939 to 1941 by Hernandez (41) He studied the following genetic characters: length and color of vine, leaf shape, skin and flesh color of roots, and time of maturity. Porto Rico, Nancy Hall, Mameyita, and several other yellow fleshed seedlings were the female parents of the progenies studied. Parents having roots of white flesh color were also used. Some of the progenies studied segregated for purple, yellow, cream and

white fleshed roots. He reported that white or cream flesh color appeared to be dominant over yellow; that flesh color seemed to be determined by dilution factors or multiple genes, and that there appeared to be a linkage between yellow flesh color and high moisture content.

In 1942, Miller and Covington (69) reported on the carotene content of roots of several seedlings. Some of these seedlings contained 50 to 97 percent more carotene than Porto Rico roots.

In 1955, Mikell et al. (61) discussed the inheritance of skin and flesh color in sweet potatoes. From the data, no genetic ratios could be calculated, but certain parents were found to transmit certain characters to a greater degree than others.

Harmon (37) found that only the seedlings from crosses between parents in the medium or high carotene range gave any appreciable number of seedlings with high carotene. Transgressive segregation was indicated by the fact that some seedlings had more carotene than either parent. Parental code L 130, Porto Rico, and HM-15 transmitted carotene better than the other parents. HM-36 used as a parent produced a fairly large number of high carotene bearing seedlings. Creole, Whitestar and Code L 21 transmitted high carotene content to only a few seedlings.

Cordner at al. (19) showed that the carotene content was raised through cross breeding to a level of about twice that obtained by selection of mutants.

The genetic variability of the foliage characters, leaf-type, stem color, and vine length has been reported by several workers. In 1942, Hernandez (41) reported on studies of progenies from several parents. He found many seedling phenotypes to be different from either parent. Inheritance of these characters seemed to be controlled by a large number of genes.

Poole (82) observed more or less continuous variation in most characters. After analyzing his data according to several different groupings, he finally concluded that some characters in the sweet potato are inherited qualitatively and others quantitatively. Stem color seemed to be inherited as a qualitative character with red color as dominant. He placed vine length into five groupings and concluded that it was quantitatively inherited with positive skewness toward the short end. He suggested that either genes for vine shortness are dominant or that shortness is due to the geometric interaction of several pairs of alleles.

Harmon (37) concluded that leaf type, stem color, and vine length appear to be inherited quantitatively. Deep cleft or lobed leaves seemed to be dominant over the entire type, but the intermediate classes appeared more often in seedlings than either the entire or deeply-cleft leaf type. Stem color appeared to be quantitatively inherited with green exerting dominance. Different patterns of the purple areas indicated that the classification and mode of inheritance of stem color might be more complex than that of leaf type or vine length. The number of genes for short vine was very limited in

the group of parents he used. Creole, Whitestar, Code L 130, and HM-36 gave progenies that were medium, long or very long in vine length.

A high percentage of the sweet potato varieties presently being grown in the main sweet potato growing areas of the United States are a result of controlled hybridization. Steinbauer (97) stated that the breeding work was directed toward obtaining new varieties with the following characteristics: resistant to cracking and diseases, satisfactory root shape and size with good skin and flesh color, high in vitamin content, good storage qualities, easy to propagate and well adapted to different areas of production. At present, no one variety incorporates all of these desirable traits, but a few new varieties have several of these desired characteristics.

Miller et al. (71) in 1960, released a new sweet potato variety, Centennial, which yields better than most other commercial varieties. The roots contain approximately 17 milligrams of carotene per 100 grams of fresh weight as compared to approximately 6 milligrams for variety Unit I Porto Rico and 12 milligrams for variety Goldrush.

In 1961, Pope, Nielsen, and Hoover (83) announced the release of a new sweet potato variety, Nugget. This variety produces a 10 percent higher yield than Goldrush and a 20 percent higher yield than Porto Rico under North Carolina conditions. Nugget is resistant to internal cork but is a symptomless carrier, and it is almost as resistant to Fusarium wilt as Goldrush.

New varieties such as Centennial (71), Nugget (83), Goldrush (66), Allgold (19), Earlyport (67), Acadian (68), Heart-o-gold (65),

Georgia Red (38), and others, have largely replaced Porto Rico, Triumph, Nancy Hall, Southern Queen and the Jersey types in commercial production.

In order to determine where carotene is synthesized in the sweet potato plant, Miller and Gaafar (70) grafted vines of varieties in which carotene was absent in the roots onto roots of high carotene varieties. They found that synthesis of carotene itself was not translocated from the leaves to the roots as such. Therefore, it would appear that the synthesis of carotene occurs in the root. This suggests that the mechanism for carotene synthesis is absent in white fleshed roots but present in yellow fleshed roots.

The site of carotenoid and anthocyanin synthesis in sweet potatoes was also studied by Kehr, Ting, and Miller (48). Neither carotenoids nor anthocyanins as such were transported through the stem of sweet potato plants to the roots. On the contrary, both carotenoids and anthocyanins were apparently synthesized "in situ," and there was no evidence found that these pigments, once they were synthesized, were translocated to other parts of the plant. The ability to synthesize carotenoid pigments and anthocyanins seemed to be governed by genetic factors found in the storage organ.

A cytological study of the carotene present in the carrot root was made by Weier (106). He noted that in differentiating cells of the carrot root, the pigment appeared either as small precipitated crystalline bodies or it was diffused generally throughout the cytoplasm. These cells contained little or no starch. In older cells

containing starch the pigment was present in the cytoplasm surrounding the starch grains. Carotene was not always found in crystalline form in the cells. When in crystalline form, it was sometimes attached to the starch grains, or it was free to move away from the grains in the streaming cytoplasm. When the carrot cells were treated with a concentration of alcohol of 85 percent or less, there was no dissolution or change in the appearance of the carotene. When they were treated with 95 percent alcohol, the carotene crystals sometimes dissolved completely or else formed a colorless residue which was soluble in chloroform.

Kohler et al. (51) found a beta-carotene concentration of 89 microgram per gram in a selected progeny of tomato. Large fruited, selections high in beta-carotene were obtained by backcrossing high carotene selections to commercial parents. The frequency with which these high beta-carotene types occurred suggested that the number of major factors necessary for high beta-carotene formation (above that present in commercial varieties) was small. Beta-carotene appeared to be produced at the expense of lycopene, since the total carotenoid concentration in the high beta-carotene selection was not increased over that of the red fruited, low beta-carotene parent.

In 1949, MacKinney and Jenkins (57) studied color variants in tomatoes. The studies concerning red (RRTT), yellow (rrTT), and tangerine (RRtt) fruited selections indicated that in the absence of R, the t gene is responsible for pigment production on a limited scale, particularly with respect to lycopene. In the absence of T, the R gene

is responsible for large quantities of carotene and pro-lycopene. In the presence of R and T, these pigments or their immediate precursors are converted to lycopene.

In 1950, Lincoln and Porter (56) studied the mode of inheritance of beta-carotene in a cross of a low beta-carotene (high lycopene) tomato variety with a high beta-carotene selection. A single gene B, incompletely epistatic to R, apparently was responsible for high beta-carotene. The gene B was considered to cause lycopene to form beta-carotene. Other genes, dominant over those for yellow and tangerine fruit color, were assumed to convert simpler compounds, including zeta carotene and phytofluene, to lycopene when present in the heterozygous or homozygous dominant state. Extremely high beta-carotene selections were not obtained in the F_2 generations from crosses of a beta-carotene parent with selections extremely high in lycopene content. A linkage of factors for high carotene and lycopene content in certain crosses was suggested.

According to Jenkins and MacKenney (45), the F_1 hybrid between yellow (rrTT) and tangerine (RRtt) tomatoes was red. The F_2 generation segregated into plants with fruit color as follows: 9 red, 3 yellow, 3 tangerine, and 1 yellow tangerine (rrtt). Dominance at both loci was considered complete. Substitution of tt genes in an otherwise red genotypic plant had no effect on the total carotenoid content but did markedly alter the individual color components. Therefore, the tt genes alter the pathway and products of pigment synthesis. On the other hand, rr genes interfered with the total carotenoid production. In an otherwise red background, rr genes produced only about

5 percent of the total carotenoids characteristic of the red fruited tomato. Contrary to expectation the double recessive (rrtt) plant had fruits with 3 to 4 times as much total carotenoid pigments as the yellow. As in the case of the yellow fruited plants, rr genes interfered with the production of all carotenoids in the yellow-tangerine fruited plants, but again the individual pigments were affected differently. The interaction at the two loci are apparently constituent pigments.

Tomes et al. (103) reported that 4 true breeding types of tomatoes are known which differ with respect to the carotenoid pigments produced in the flesh of the fruit. Three of these, the red, the yellow, and the beta-orange, are characterized by quantitative shifts which involve the pigments lycopene and beta-carotene. The fourth type, Jubilee, a variety of orange color, possesses a different pigment system in which zeta-carotene and pro-lycopene are the major components. It was shown that these pigment systems depended upon the action of 3 independent genes, R, T, and B. Genes R and T were shown to be dominant chemically as well as visually. With regard to B, it was suggested that this gene lacked dominance. The primary action of gene R appeared to be the production of an unknown precursor. Gene T converted pigments of the Jubilee system into a lycopene-beta-carotene system, and B determined the relative proportions of lycopene and beta-carotene in the presence of R and T. Tomes et al. (87) further stated that the alleles B/b governed the occurrence of high or low concentrations of beta-carotene. The gene B was originally

designated as an incomplete dominant gene. Evidence was presented to show that B was dominant and that the intermediate nature of the F_1 progeny, as well as the F_2 distribution, may be explained by the interaction of B with a modifier contributed by the low beta-carotene (red, high lycopene) parent. Varying the genotype with respect to B and its modifier provided 4 homozygous tomato types with 4 different provitamin A levels.

Fertilizer Effects on Carotene

Samuels et al. (87) reported that nitrogen applications which increased the yield of sweet potato roots also increased their carotene content. Increases in the carotene content of sweet potato roots were obtained with phosphorous only when the yields were significantly increased by the addition of this element. Although potash applications resulted in yield increases, no significant effect on carotene content of the roots was noted, except in one experiment on a Catano loamy sand where a decrease in carotene resulted. The carotene content was measurably affected by the use of $CaCO_3$ on acid soils. Increases in soil PH gave an increase in carotene in the roots. The carotene content in the roots was not affected by the addition of Mg, Cu, or Mn to the soil.

According to Greig et al. (34), additions of Na to growth media reduced both the weight and the carotene content of the fleshy roots, but increased the vine weight. A high potassium treatment significantly increased the carotene content of the fleshy roots. Accumulation of cations by the fleshy roots generally occurred in proportion

to the quantity of cations added to the soil.

Speirs et al. (94) found that fertilization with various combinations of nitrogen, phosphorous, potassium, and calcium had relatively little effect on the carotene content of the Unit I Porto Rico roots. This is in agreement with Swanson et al. (99) who concluded that the type of fertilizer used in the soil did not significantly affect the vitamin A content of the sweet potato roots produced.

Environmental Effects on Carotene

The effects of curing and storage of roots on the carotene content of sweet potatoes have been studied by several workers, but the results have varied widely. MacLeod et al. (58) found that the Porto Rico and Yellow Jersey contained three and four times, respectively, as much vitamin A after storage for two months or longer, than was present at harvest. Miller and Covington (69) noted an increase of 50 percent in the carotene content of the Porto Rico variety during one month of storage and a subsequent slight rise in the second month to a level which remained unchanged during the third month. Spears et al. (94), also working with the Porto Rico variety, found that the original carotene content was retained from the time of harvest through curing and six months of storage under controlled conditions. Miller et al. (72) reported an increase in the beta-carotene content of some varieties during the first month in storage at 75°F. and a decreese after 4 months of storage. Goodson (32) studied a group of selected seedlings for the effects of various storage periods on the carotene

content. All of the varieties and seedlings except three increased in carotene during the first month in storage. All samples decreased in carotene content during the second month, but increased during the third month with the exception of one seedling and Unit I Porto Rico. Unit I Porto Rico showed an increase in carotene content during each of the four months of storage.

In a study of five varieties of sweet potatoes, Ezell and Wilcox (25) determined the beta-carotene and total carotenoid content of Yellow Jersey, Nancy Hall, Unit I Porto Rico, and Orange Little Stem varieties at harvest, after curing, and at intervals during storage at 50°, 60°, and 70°F. It was evident from their data that temperature played an important part in carotenoid changes in storage. At 50°F. there was little, if any, increase in carotene or total pigments in most of the varieties. At 55°F, there was an increase in carotene in all of the varieties except Nancy Hall. This variety lost carotene and total pigments during storage at all temperatures. At 70°F. the carotene and total carotenoids increased less rapidly than at 60°F. except in Yellow Jersey.

Mac Nair (59) stored sweet potato varieties Golden Bell and Allgold under common storage conditions. These varieties lost very little carotene during the first three months, but lost an appreciable amount during the second three months of common storage. After six months Allgold had a carotene content that was two and a half times that of the other varieties studied.

Ezell et al. (27) also studied the beta-carotene and total carotenoid pigment content of several varieties harvested at nine different

dates varying from mid-August to late November. The date of harvest (early, midseason, or late) appeared to be of less importance in determining the post harvest behavior of the carotenoid pigments in the roots than did the pre-harvest environmental factors. Kimbrough et al. (49) also found that roots of the Porto Rico variety planted in July were lower in carotene content at harvest time than those from earlier plantings. Roots harvested from plots planted at monthly intervals, running from April through June, did not differ in carotene content at harvest. Early harvested roots of usable size were as high or higher in carotene than those from the same planting harvested at a later date.

Edmond et al. (22) studied the effects of time of harvest and length of the storage period on the intensity of flesh color in sweet potatoes. The variety Porto Rico was planted at four locations annually for two or three years. Although some inconsistencies were noted at some locations and in some years, the data generally showed that flesh color of the roots increased as the time of harvest was delayed. In every test, except for one year at one location, roots examined 13 to 34 weeks after storage had more intense flesh color than corresponding lots examined at harvest.

The effect of date of planting on the carotene content of the Porto Rico variety was also studied by Anderson et al. (4) in tests conducted for three years at one location. They found no difference in the carotene content of roots from early (April) or mid-season (May) plantings, but a decrease in carotene content was obtained from late (June, July) plantings.

Ezell et al. (28) reported that the relative humidity of the storage room had little effect on the carotene pigments in the sweet potatoes. Roots of Orange Little Stem and Yellow Jersey varieties of sweet potatoes were cured and then stored at 60°F. and 70-75 percent, 80-85 percent and 95-100 percent relative humidity. Carotenoid pigment increased in the roots at all humidities.

Nishida et al. (76) stated that carotene in the sweet potato is destroyed by heat, sunlight, atmospheric oxygen and certain enzymes. Working with sweet potato "mash," the authors found that 5 percent of the carotene was lost by blanching the samples for 20 minutes while the peroxide enzyme was inactivated. Also, 7 percent of the carotene content was lost when sweet potato flour was dehydrated after blanching for 30 minutes. Sun drying the flour destroyed more carotene than did dehydration, and carotene was completely destroyed by irradiation. Atmospheric oxygen was also destructive to carotene, while carbon dioxide gas and KCN prevented carotene destruction.

Results on enzyme studies by Nishida et al. (76) suggested the existence of lipoxidase which influenced the destruction of carotene in the sweet potato. Evidently this enzyme is an important destructive factor of carotene.

Scott and Kattan (91) found that sweet potato varieties responded differently to catechol oxidase which causes discoloration of sweet potato roots during preparation for processing. The degree of activity of this enzyme was found to be negatively correlated with

the intensity of flesh color of the roots. It was suggested by the authors that the catechol oxidase activity test be used as an aid in the evaluation of seedlings for processing qualities.

In 1941, Anderson (3) stated that it was unwise to keep samples of sweet potato under ordinary laboratory storage conditions for long periods of time if carotene determinations are to be of value. In his experiment sweet potato carotene samples lost 15 percent of their total carotene content after four weeks, 25 percent after two months, 35 percent after three months, and 52 percent after 4.5 months of storage at room temperature and humidity.

Arthur and McLemore (7) studied the effects of processing treatments on the chemical properties of Unit I Porto Rico and Goldrush varieties of sweet potato. The beta-carotene content of canned roots was relatively stable during processing with values of 20 to 25 milligrams per No. 2 can of Unit I Porto Rico and 40 to 45 milligrams per No. 2 can of Goldrush.

Sayre et al. (88) made a study of the effect of temperature on the color, lycopene, and carotene content of tomatoes. At a temperature range of 65° to 80°F., the fruits were well colored and high in carotene and lycopene content. Tomatoes ripened at 85° to 100°F., were yellow to orange in color and never developed sufficient lycopene (red color) to meet even U. S. No. 2 grade. At 45° to 60°F. tomatoes ripened so slowly that they became soft but eventually developed good red color. This is in agreement with Denisen (21) who stated that shading the tomato fruits by plant foliage during the ripening period

produced a deeper red color in them than in fruits exposed to full sunlight. The optimum temperature for ripening Rutgers and Jubilee tomatoes in storage was found to be 20° to 25°C. with regard to maximum color development.

Brown (15) stated that carrots showed a general tendency to increase in carotene content in storage up to 20 weeks, then to remain fairly constant up to 30 weeks. At 15 weeks, the carotene content had dropped to the 5 week level; however, the carrots regained the loss at 20 weeks.

According to Banga and DeBruyn (10) carotene comprises about 90 percent of the total carotenoids in carrots. Carotenoid content increases with the development of the carrot until the maximum size is reached.

Carotene Determinations

The discovery by Borodin (13) in 1883 that the carotenoid pigments could be separated into alcohol soluble and petroleum ether soluble groups has been the basis for all of the procedures that have been described for the determination of beta-carotene and other carotenoid pigments. In 1887, Arnaud (6) extracted pigments from dry plant tissue with petroleum ether and used a colorimetric method for the estimation of the amount of pigment present, a carotene solution being employed as a standard. No attempt was made to separate carotene from other yellow pigments and the purity of the carotene standard was not given. In 1913, Monteverde and Lubimenko (74) reported a spectro-colorimetric method for the estimation of the pigments of

green leaves, and in the same year Willstatter and Stoll (107) presented a method for the determination of carotene and xanthophyll which has served as the starting point for all subsequent modifications. The latter method consists essentially of acetone extraction of plant tissue, saponification of chlorophyll, separation of the carotenoids by means of petroleum ether and aqueous methyl alcohol, and the colorimetric estimation of the pigments. A petroleum ether solution of carotene or an aqueous solution of potassium dichromate served as a colorimetric standard. In 1926, Coward (20) modified the procedure by making the first step in the decomposition of chlorophyll, which was followed by extraction with petroleum ether and the separation of carotene from xanthophyll by aqueous methyl alcohol. The use of diethyl ether in addition to acetone in pigment extraction from plant tissue was introduced by Schertz (90) in 1928. In 1923, he described a method (89) for the spectrophotometric estimation of carotene. Sprague and Shive (95), 1929, employed the method as modified by Schertz (90), except that they used petroleum ether rather than diethyl ether as a solvent for the carotenoids. These investigators and Sprague and Troxler (96) developed a color standard of dye solutions for use in colorimetric measurements.

Pyridine was employed by Smith and Smith (93) for the extraction of pigment from small quantities of fresh fruit, the pigments being transferred to petroleum ether. Kuhn and Brockmann (53) have described the use of petroleum ether and methyl alcohol in the extraction of pigment in plant tissue with the subsequent separation into petroleum ether and aqueous methyl alcohol phases. After these steps

saponification with alkali in the petroleum ether phase was followed by a further partition between petroleum ether and 90 percent methanol. The use of suitable absorption agents allowed the separation of alpha- and beta-carotene from lycopene in the petroleum ether phase. A solution of azobenzene was used as the colorimetric standard.

Both spectrophotometric and colorimetric methods have been used by various investigators in estimating the concentration of carotene in the petroleum ether solution obtained by the analytical procedure. The former method has been described by Schertz (89) and by Ferrari and Bailey (30). However, the error involved in the isolation of carotene is probably as great as that inherent in the colorimetric method, and therefore there seems to be no advantage in the use of the spectrophotometric procedure for which greater accuracy has been clained by Schertz (89).

Methods were later proposed, such as that by Ottman (78), which involved the measurement of the intensity of transmitted light by means of a photoelectric cell and was intended to eliminate the subjective factor inherent in colorimetric measurements.

According to Beadle and Zscheile (11), most of the methods proposed for the determination of carotene pigments in plant materials up to 1942 were modifications of the original method of Willstatter and Stoll (107). The final carotene solution, after being extracted from the plant tissue with a solvent, saponified, and distributed between immiscible solvents, was then analyzed by comparison if its light-absorbing properties in a specified wave band with those of a carotene

standard. In such comparative methods of pigment determination it was assumed that all the pigment in the final petroleum ether solution was beta-carotene. Generally, no accurate allowance was made for the presence of colored impurities. Miller (62) applied a spectrophotometric method to the analysis of certain plant extracts for beta-carotene without separation of chlorophyll and xanthophyll pigments. He observed that the spectroscopic properties of the carotene of the plant extract and of the beta-carotene reference standard did not agree. This has been discussed by Wiseman et al. (108), by Peterson et al. (80), and by Peterson (79).

Various attempts were made to develop a method which limited the pigment to beta-carotene. Fraps et al. (31) used selective absorbents in the preparation of the final petroleum ether solution. Moore (75) filtered the pigment extract through a short column of dicalcium phosphate. Hegstad et al. (40) and Zimmerman et al (109) used aqueous diacetone alcohol for separation of the non-carotene pigments from the solution.

According to Lease and Mitchell (55), methods involving the use of alcoholic potassium hydroxide were found inapplicable to cooked sweet potatoes, stored raw sweet potatoes, and certain other cooked vegetables because subsequent extraction of carotene was incomplete. Apparently, polymerization of carbohydrate by the alkali, forming a resinous film, rendered the carotene unextractable by cold or boiling 95 percent ethanol, ether, acetone, or petroleum ether. In samples containing large amounts of carbohydrates, carotene may be determined by extraction with ethanol. If alcoholic potassium

hydroxide is used, the material should be subsequently boiled with water to dissolve the resins before extraction of the carotene by fat solvents.

Zscheile and Beadle (110) showed that considerable error may be introduced into photometric methods for the analysis of carotene extracts if the content of neo-beta-carotene is not considered. Beadle and Zscheile (11) successfully applied a photo-electric spectrophotometric method to the carotene analysis of certain vegetables.

In 1944, Silker et al. (92) discussed a new carotene extraction procedure used on dehydrated alfalfa. Carotene was extracted by allowing a sample of dehydrated alfalfa to stand 16-18 hours in the dark in a mixture of Skellysolve B and acetone. A chromatographic separation of carotene from other pigments was made on a column of 2 parts Hyflo Super Cel and 1 part magnesia. Analysis of the carotene was done with a Beckman spectrophotometer. The results, compared with that of two of the more common methods of analysis, were satisfactory. The new procedure caused some isomerization of the carotenoids, but less than methods requiring refluxing of the solution. A consideration of the degree of isomerization was necessary because of the probable reduced nutritional value of the isomeric pigments.

In the same year, Austin and Shipton (8) described a method which consisted of heating the plant material with aqueous KOH, refluxing after addition of absolute ethyl alcohol, filtration, extraction of the filtrate with petroleum ether, washing the petroleum ether phase with water, drying over anhydrous Na_2SO_4, chromatographing on a

column of activated MgO, and elution of the carotene with 10 percent acetone in petroleum ether. The carotene in the eluate was measured photometrically.

In 1946, O'Connor et al. (77) described a carotene extraction method designed for use in sweet potatoes and sweet potato products. The three essential steps in the analysis for carotene, extraction, purification, and spectrophotometric measurement, were used and a modified method proposed. Inconsistencies in the use of published extinction coefficients for carotene in petroleum ether fractions were not due solely to the presence of non-carotene impurities in solutions, but to the variable character of these mixed solvents. Extinction coefficients were determined in an easily purified solvent, iso-octane, in which case the same supply of solvent can be used repeatedly. The authors concluded that for a satisfactory determination of carotene in the sweet potato, a complete extraction of the unchanged carotene needed to be carried out without saponification and without heating. Of various solvents tested for their relative efficiency in the extraction of carotene, cold ethyl alcohol (95%) proved the most satisfactory.

Kramer (52) in 1954 reported on the possibility of using a photoelectric tristimulus colorimeter such as the Hunter color difference meter for measuring color in certain foods. The advantages claimed for this method were its rapidity and the combination of quantitative and descriptive evaluation of the color in one determination. This type of instrument was used with several food products,

including different sweet potato varieties and breeding lines. Kattan et al. (46) reported a high multiple correlation coefficient of +0.94 existed between carotenoid content and Hunter aL and bL values.

Hoover (44) stated that puree blends of several varieties of sweet potatoes were canned and color measurements were made with the Hunter Color Meter. The varieties of sweet potatoes were selected so that a high and low colored puree could be produced. After color measurements were made on the various blended samples with the Hunter Color Meter, aliquots of the well mixed samples were taken and the total carotene content determined. Munsell color notations and ICI specifications of color were also obtained for each sample. The Hunter Color Meter readings, carotene content, and Munsell color notations were then correlated.

A very high correlation was found between "Hunter a" reading and carotene content within each series of blends made from two varieties. However, when the regression formula obtained for one set of puree blends was applied interchangeably between other blends from different varieties, a poor fit was obtained. A very high linear correlation was found to exist between "Hunter a" and "Munsell hue." The regression formulas for "Hunter a" and "Munsell hue" could be applied interchangeably between blends of the different varieties with an excellent fit. When all samples of the various blends were grouped together and the "Hunter a" reading and carotene content correlated, a correlation coefficient of 0.90 was obtained. A correlation coefficient of -0.988 was obtained when "Hunter a" reading was

correlated with "Munsell hue."

The tendency for puree made from some varieties of sweet potatoes to discolor more than others was probably the main factor responsible for the relatively poor correlation found between "Hunter a" reading and carotene content in grouped samples. However, as indicated by the high correlation which existed between "Hunter a" reading and "Munsell hue," the Hunter Color Meter could be very useful for determining and standardizing the color of sweet potato puree.

Ahmed and Scott (2) also indicated that high correlation coefficients existed between Hunter color attributes and the logarithm of carotenoid content. Of the various Hunter color meter values, the "a" scale seemed to be best suited as a rapid method for the evaluation of sweet potato carotenoid content. However, Ezell et al (29) stated that although a highly significant multiple correlation coefficient of +0.78 between total carotenoids and Hunter Rd, A_{Rd} and b_{Rd} values was obtained, the correlation was not sufficiently close to give assurance that even large differences in carotenoid content would be detected by the Hunter color meter.

Incompatibilities

Apparently the first successful attempt to establish a breeding program based on sexual reproduction was that of Miller and his colleagues at Louisiana State University in the late 1930's (63). Starting with this work, several reports (16, 19, 23, 32) have been published in recent years dealing with sexual reproduction of the

sweet potato in the United States of America.

One of the first recognized problems in sexual reproduction was the sparsely-flowering habit of the species. Bailey in the Standard Cyclopedia of Horticulture (9) stated that flowers and fruits are rarely seen. Incompatibility and sterility were recognized as a major problem then.

Thompson (100), Toutine (104), Miller (63), and Abraham (1) have reported on the widespread sterility problem encountered in sweet potato breeding.

Kazuma et al. (47) reported in 1955 that most American varieties of sweet potato flowered sparsely. They found complete incompatibility between some clones and a high degree between others.

In 1946, Edmond and Martin (23) obtained 1.5 percent capsule set from selfing and 37.0 percent from crosses among several clones. The pollinations were made in the greenhouse.

In 1938, Brown (16) studied the effects of technique, time of pollination, and environment on seed set and found that seed set between compatible clones could be improved. He found that pollinations made from 8:00 to 10:00 a.m. were the most successful in the fall and those from 6:00 to 9:00 a.m. best in the spring. A minimum temperature of 65 to 70 degrees F. gave best results in his studies. He also found that thinning of the flowers increased seed set.

In 1950, Montelaro (73) found no significant difference in compatibility when a clone was used as male or female parent. He observed high self incompatibility in most of the clones studied.

Parental Code 130 was self compatible in these experiments.

Harmon (37) stated that compatibility varied from zero to 100 percent. In crosses consisting of over 50 pollinations, 81.66 percent capsule set was the highest obtained. His three studies on compatibility involved 11 clones selfed and 80 different crosses among 17 clones. The average percent capsule set was 16.76. Generally, a clone that was highly compatible with any one clone was also compatible with most other clones and equally compatible when used as a male or as a female parent. Porto Rico was an exception to this generalization, setting a much higher percentage of capsules when used as a female parent. Certain other reciprocals differed greatly in this respect also.

Hernandez and Miller (42) found that self and cross incompatibility was common among certain breeding lines. In further studies, they (43) reported that of 19 breeding parents used in the study, only three were highly self compatible, namely, Kandee, L3-80, and Centennial. Progenies grown from these selfed parents showed that in many cases the seedlings were low in vigor.

Cross incompatibility was also common among the breeding lines used in their studies (43). Breeding line L3-7 was highly cross compatible with L138 and L1-80, but it was cross incompatible with L3-77 and Unit I Porto Rico. Goldrush was found to be self and cross sterile as a female parent, but fertile in some cases as a male parent. This is in agreement with Ting et al. (102), who also reported this condition in Goldrush.

MATERIALS AND METHODS

Parents Used

A total of 28 sweet potato breeding parents was selected for this study. The compatibility behavior and phenotype of each parent was known. These parents, as shown in Table 1, were selected because of their desirable horticultural characters and known compatibilities. Of the 28 parents used, all were Louisiana Agricultural Experiment Station varieties or advanced F_1 seedlings except Georgia Red, Kandee, Whitestar and seedlings P.I. 213321B and P.I. 227890.

Pollination Technique

Controlled pollinations were made in a field plot breeding nursery and a greenhouse 20 x 120 feet where the sweet potato plants were trained onto a six foot netted chicken wire trellis. The sparse flowering clones were cleft-grafted on morning glory (Ipomoea sp.) root stock. The breeding clones were transplanted into the breeding nursery and screenhouse in April of each year. Pollinations were begun in August and continued until October 25 of both years. In the breeding nursery, large soda straws were used to protect the pistil from contamination by insects before and after pollination. Controlled pollinations were made daily in the morning, between 5:00 and 9:00 a.m. Pollen of each male parent was collected each morning from flowers protected by straws.

TABLE 1: Data On Parents Used for Controlled Crosses

Name of Parent	Skin Color	Percent Dry Matter	Total Carotenoid Content (observed)[a]	Total Carotenoid (actual) mg./100 gm.	Color Difference Meter Readings L	aL	bL
Centennial	Copper-tan	29.01	4	16.1	62.5	33.1	31.8
Georgia Red	Rose	29.26	3	5.2	67.8	22.5	30.3
Goldrush	Copper	28.10	4	14.5	66.6	26.7	30.3
Heartogold	Cream	25.99	2	6.0	66.7	14.3	28.9
Kandee	Light copper	28.74	3	4.6	74.7	17.3	27.3
Pelican Processor	White	38.42	0	0.0	89.2	-13.3	19.0
Unit I Porto Rico	Copper	29.43	3	5.2	75.3	11.1	30.3
Whitestar	Cream	34.27	1	0.4	81.6	-10.5	21.5
P.I. 213321B	White	29.53	0	0.0	84.0	-19.8	15.8
P.I. 227890	Purple	36.61	0	0.0	83.8	- 9.1	14.3
L 21	Light copper	32.56	1	1.2	71.5	0.7	28.8
L 130	Rose	31.26	2	4.2	69.2	17.4	30.5
L 131	Cream	29.59	4	7.0	64.9	27.4	30.1
LO-34	Light copper	24.83	5	22.2	64.1	31.5	31.6
LO-43	Light copper	27.02	3	8.6	69.9	17.8	30.0
LO-99	Tan	30.32	5	19.0	64.2	29.8	29.7
LI-80	Copper	29.43	5	18.0	65.5	28.0	30.6
LI-171	Rose	27.19	5	16.0	59.2	28.5	29.5
LI-183	Copper	25.54	4	14.5	65.2	27.2	30.1
L2-61	Purple	30.57	3	8.6	64.8	23.6	28.7

(continued)

TABLE 1 (Continued)

Name of Parent	Skin Color	Percent Dry Matter	Total Carotenoid Content (observed)[a]	Total Carotenoid (actual) mg./100 gm.	Color Difference Meter Readings L	aL	bL
L3-7	Copper	36.48	4	11.7	71.9	16.9	30.6
L3-64	Rose	30.76	4	11.0	65.8	23.5	29.7
L3-80	Rose	30.84	4	10.4	65.3	24.1	30.1
L3-93	Tan	28.16	3	16.0	65.2	26.4	30.8
L7-142	Rose	26.39	4	14.5	67.0	26.0	30.9
L8-3	Copper	28.37	5	18.5	69.9	35.6	32.3
L8-31	Copper	24.25	3	9.8	66.1	26.9	31.1
L8-67	Rose	27.16	4	17.5	56.1	36.2	29.8

[a]0 - no carotene, as variety Pelican Processor.
1 - cream, as variety Whitestar.
2 - light carotene, as breeding parent L 21.
3 - medium carotene, as variety Unit I Porto Rico.
4 - high carotene, as variety Goldrush.
5 - very high carotene, as variety Centennial.

The flowers used as females were emasculated and covered with a straw the day prior to pollination and each pollinated flower was labeled as to parentage.

Growing and Harvesting F_1 Seedlings

In January of each year, the seeds were scarified in concentrated sulfuric acid for 20 minutes, thoroughly washed and dried. The seeds were then planted in greenhouse benches filled with a mixture of shredded sphagnum moss and silt loam soil. The seedlings were allowed to grow until May, 1961, at which time they were pulled and transplanted to the field 5 feet apart on rows 4 feet wide. The seedlings were allowed to grow under field conditions until September at which time they were harvested. The roots from each hill were placed in a paper bag, labeled and assigned a number for identification.

Approximately 1500 seedlings were moved to the laboratory and evaluated for dry matter content, and total carotenoid pigment content, skin color, and used for Gardner color difference meter measurements.

Skin Color Classes

Each seedling was classified for skin color by visual observations and placed into one of 6 skin color classes. As shown in Plate 1, the skin color classes used were: white, cream, tan, copper, rose and purple.

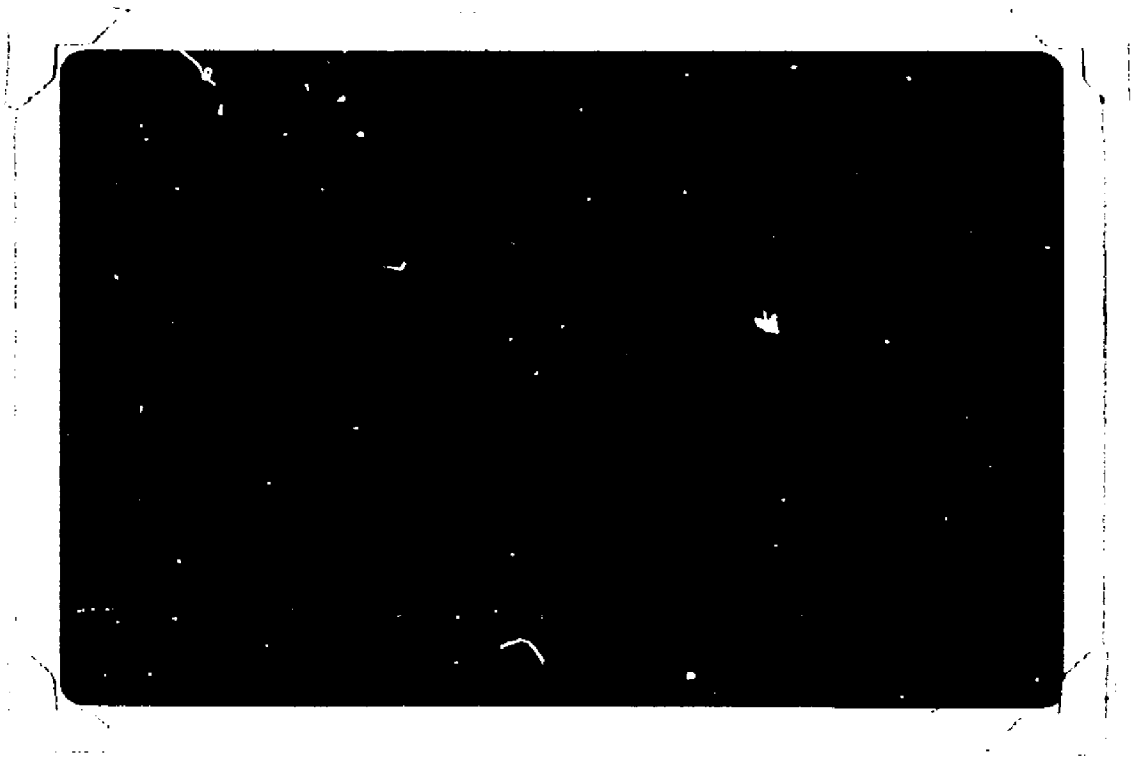

PLATE 1: Skin Color Classes

Total Carotenoid Classes (Visual)

The roots of each seedling were cut in half and given visual readings for intensity of total carotenoid pigments. As shown in Plate 2, the visual classes used were:

0 - no carotene, as variety Pelican Processor

1 - cream, as variety Whitestar

2 - light carotene, as breeding parent L21

3 - medium carotene, as variety Unit I Porto Rico

4 - high carotene, as variety Goldrush

5 - very high carotene, as variety Centennial

PLATE 2: Visual Classes for Total Carotenoid Pigments

Gardner Color Difference Meter Readings

A slice approximately 3/4-inch in thickness was cut horizontally from the center section of each root. Immediately after the section was cut, L, a_L and b_L readings were made on the Gardner color difference meter.

Analytical Procedure Used for Total Carotenoid Pigment Determinations

After a cross section slice was cut from each root, a small amount of the remaining root next to the section of the slice was grated and the total carotenoid content was determined by quantitative analytical procedures similar to those described by O'Connor et al. (77).

A 5 gram sample was obtained from the grated tissue to which approximately 100 millimeters of cold 95 percent ethyl alcohol was added. The sample was blended for 5 minutes at 100 RPM and then filtered through a sintered-glass funnel using a partial vacuum. The residue left on the funnel was washed with small portions of the two solvents, ethyl alcohol and iso-octane. The filtrate was then transferred to separatory funnels and 100 milliliters of cold, distilled water and 2 to 3 grams of sodium chloride were added. When the two solution phases separated, the alcohol and water layer was transferred to a second funnel. This solvent was extracted with 25-30 milliliters of iso-octane by adding an iso-octane layer to the first funnel. This process was continued until the iso-octane remained colorless. The iso-octane solution was then filtered through anhydrous sodium sulfate and made up to a volume of 200 milliliters in volumetric flasks. A small amount of this filtrate was poured into appropriate glass tubes and the percent light transmission measured with the Spectronic 20 photocolorimeter. The carotene content was then calculated from a standard curve established with the same instrument.

Dry Matter Determinations

From the grated samples of each root, a 10 gram portion was weighed for dry matter determinations. The weighed wet samples were placed into weighed metal containers and dried in a drying oven for 24 hours at 70°C. the dried samples were then placed into a desiccator to cool, after which they were weighed again. The percent dry matter was then calculated.

RESULTS AND DISCUSSION OF RESULTS

Inheritance of Total Carotenoid Pigments

The data showing the number of F_1 seedlings in each total carotenoid class from different parental combinations are shown in Table 2. The percentage of the total number of seedlings in each total carotenoid class from several parental combinations is shown in Table 3 and in Figures 1 through 12.

Whenever a female parent with roots of a white flesh was crossed with a male parent with roots containing 2 mg. total carotenoid pigments/100 gm. fresh weight of root tissue, 98.0 percent of the seedlings, as shown in Figure 1, had roots with little or no pigment. The mean total carotenoid content of the roots of the F_1 seedling population was .186 mg./100 gm. fresh weight. When female parents with roots of a white flesh color were crossed with a male parent having roots containing 18 mg. total carotenoid pigments/100 gm. fresh weight of root tissue, 164 out of 195 seedlings or 84.1 percent of the seedlings had little or no carotenoid pigments. The remaining seedlings fell into other carotenoid pigment classes of which only 0.5 percent of the seedlings had as much total pigments as the highest parent. The mean total carotenoid content for the total F_1 progeny was 1.338 mg./100 gm. fresh weight. This indicates that white flesh color is incompletely dominant over orange flesh color.

TABLE 2: Frequency Distribution of F_1 Sweet Potato Seedlings into Different Total Carotenoid Pigment Classes

Parental Cross* mg./100 gm. Root Fresh Weight Basis	Total Number of F_1 Seedlings	Number of F_1 Seedlings in Each Class Mg. Total Carotenoid pigments/100 gm. Root(Fresh Wt.) 0-3	3-6	6-9	9-12	12-15	15-18	18-21	Over 21	Mean Total Carotenoid Content
6 mg. (X)	41	27	7	3	2	1	0	0	1	2.837
18 mg. (X)	57	16	3	4	5	3	12	3	11	11.652
0 mg. x 2 mg.	153	150	2	0	1	0	0	0	0	0.186
0 mg. x 18 mg.	195	164	21	6	3	0	1	0	0	1.338
2 mg. x 18 mg.	67	25	16	4	6	8	4	1	3	6.660
6 mg. x 16 mg.	65	4	13	6	16	14	7	4	1	7.170
6 mg. x 12 mg.	139	33	29	21	18	19	14	4	1	8.284
6 mg. x 18 mg.	264	29	31	27	22	43	34	39	39	12.861
12 mg. x 12. mg.	150	32	17	16	13	18	36	5	13	12.246
12 mg. x 18 mg.	282	48	26	22	30	26	39	38	53	13.847
18 mg. x 18 mg.	147	17	6	6	12	17	16	29	44	15.800

*Parental cross represents female and male parents, respectively.

TABLE 3: Percentage of F_1 Sweet Potato Seedlings into Different Total Carotenoid Pigment Classes

Parental Cross* Mg. Total Carotenoid/100 gm. Root Fresh Weight Basis	Total Number of F_1 Seedlings	Percent of F_1 Seedlings in Each of the Following Total Carotenoid Classes Mg. Total Carotenoid Pigments/100 gm. Root (Fresh Weight Basis)							
		0-3	3-6	6-9	9-12	12-15	15-18	18-21	Over 21
6 mg. (X)	41	65.9	17.1	7.3	4.9	2.4	0.0	0.0	2.4
18 mg. (X)	57	28.1	5.3	7.0	8.8	5.3	21.1	5.3	19.1
0 mg. x 2 mg.	153	98.0	1.3	0.0	0.7	0.0	0.0	0.0	0.0
0 mg. x 18 mg.	195	84.1	10.8	3.1	1.5	0.0	0.5	0.0	0.0
2 mg. x 18 mg.	67	37.3	23.9	6.0	8.9	11.9	6.0	1.5	4.5
6 mg. x 6 mg.	65	6.2	20.0	9.2	24.6	21.5	10.8	6.2	1.5
6 mg. x 12 mg.	139	23.7	20.9	15.1	12.9	13.7	10.1	2.9	0.7
6 mg. x 18 mg.	264	11.0	11.7	10.2	8.3	16.3	12.9	14.8	14.8
12 mg. x 12 mg.	150	21.3	11.3	10.7	8.7	12.0	24.0	3.3	8.7
12 mg. x 18 mg.	282	17.0	9.2	7.8	10.6	9.2	13.9	13.5	18.8
18 mg. x 18 mg.	147	11.6	4.1	4.1	8.2	11.6	10.9	19.7	29.8

*Parental cross represents female and male parents, respectively.

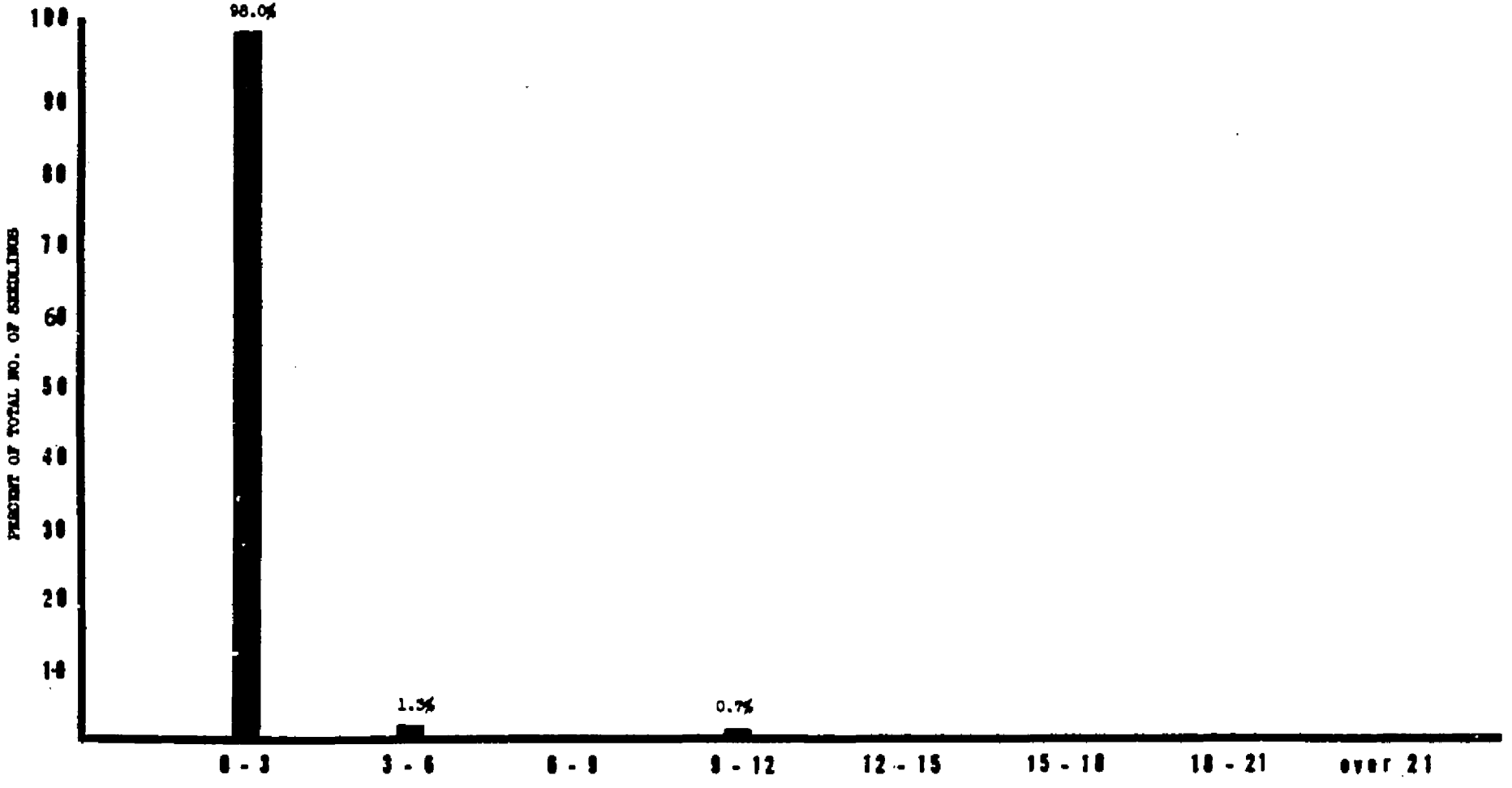

FIGURE 1: CLASSES IN MG/100 GMS TOTAL CAROTENOID PIGMENTS

FEMALE PARENT - 0 MG/100 GMS TOTAL CAROTENOID PIGMENTS

MALE PARENT - 2 MG/100 GMS TOTAL CAROTENOID PIGMENTS

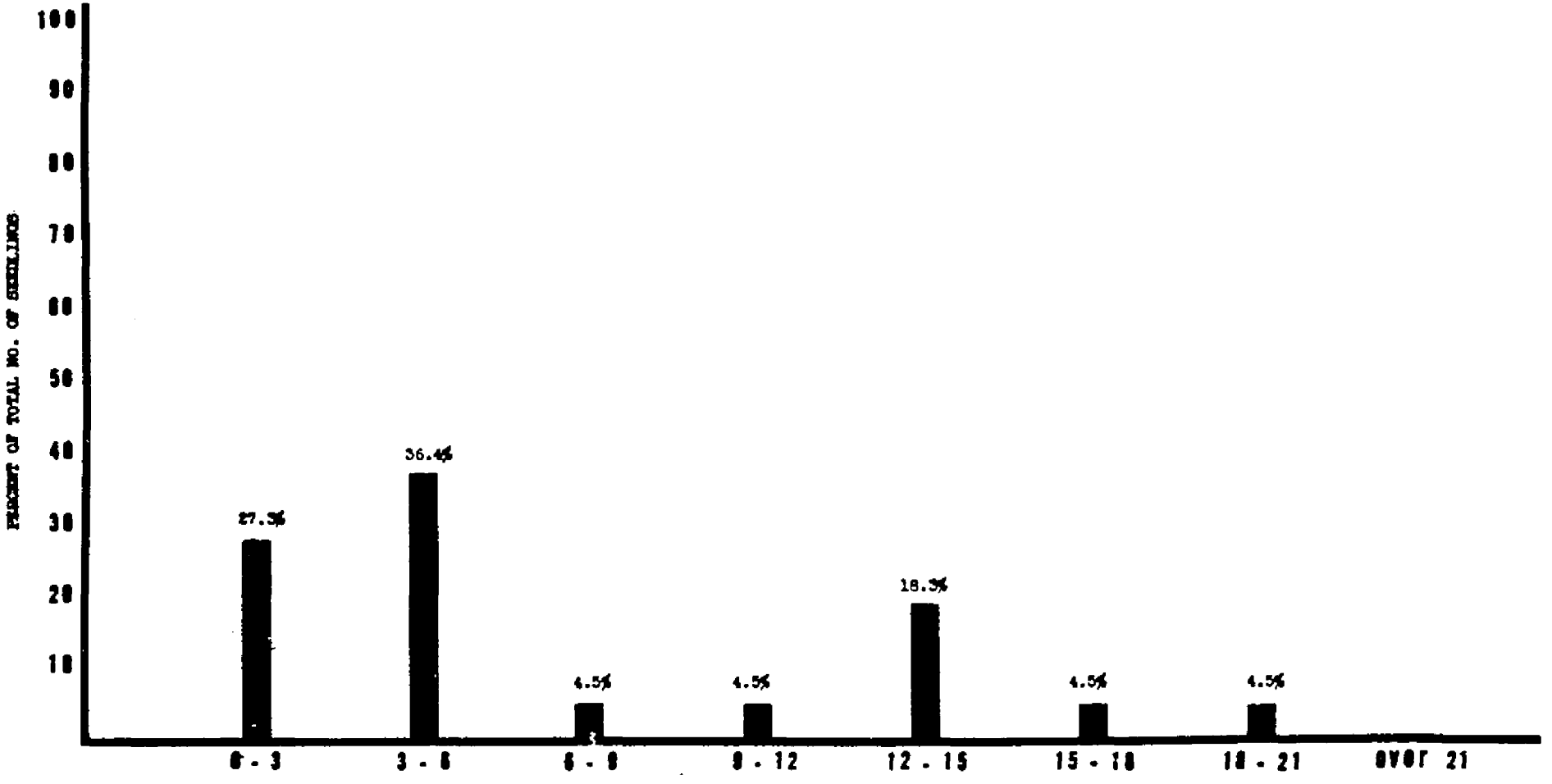

FIGURE 2: CLASSES IN MG/100 GMS TOTAL CAROTENOID PIGMENTS
FEMALE PARENT - 0 MG/100 GMS TOTAL CAROTENOID PIGMENTS
MALE PARENT - 12 MG/100 GMS TOTAL CAROTENOID PIGMENTS

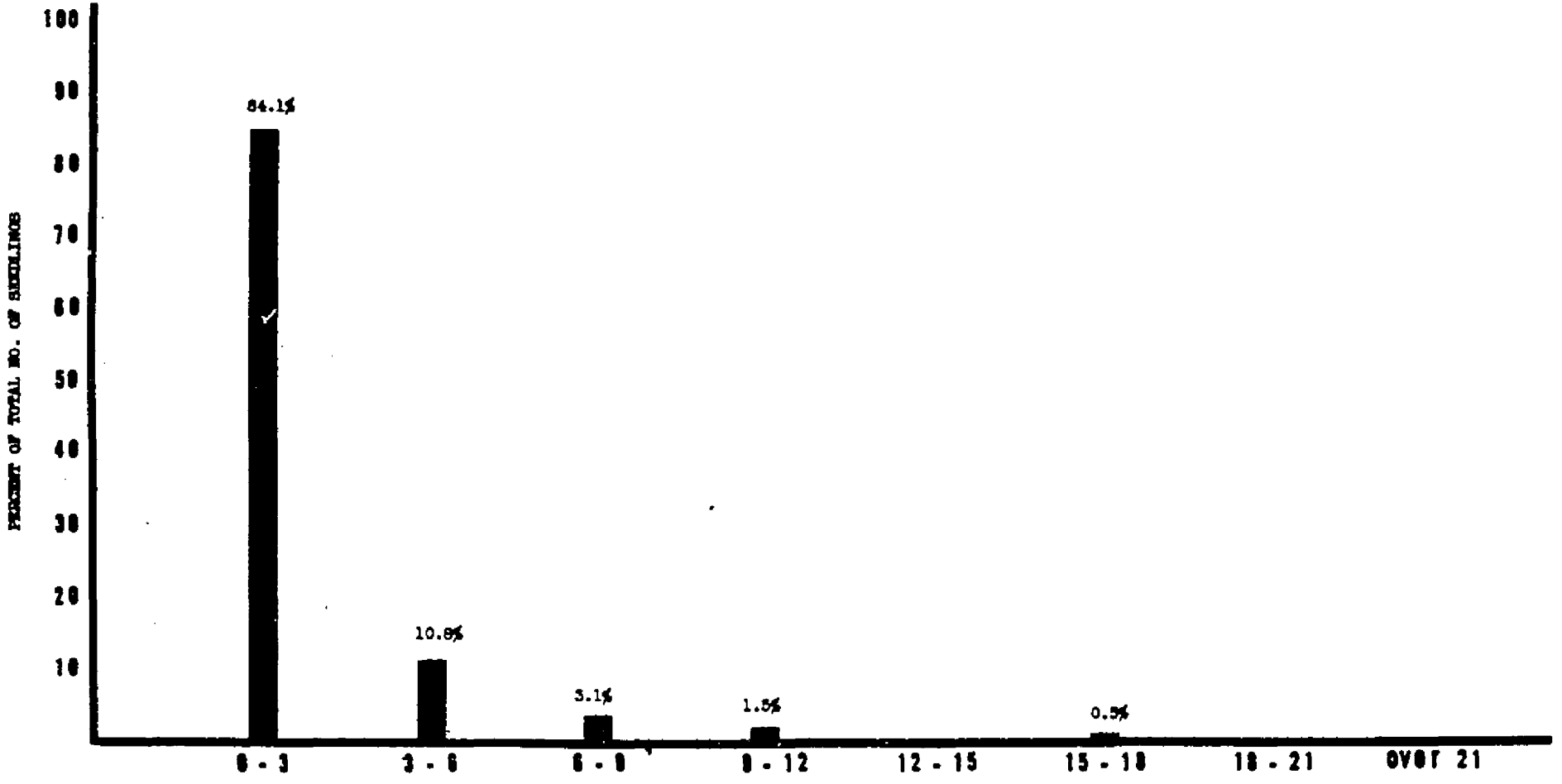

FIGURE 3 : CLASSES IN MG/100 GMS TOTAL CAROTENOID PIGMENTS
FEMALE PARENT - 0 MG/100 GMS TOTAL CAROTENOID PIGMENTS
MALE PARENT - 18 MG/100 GMS TOTAL CAROTENOID PIGMENTS

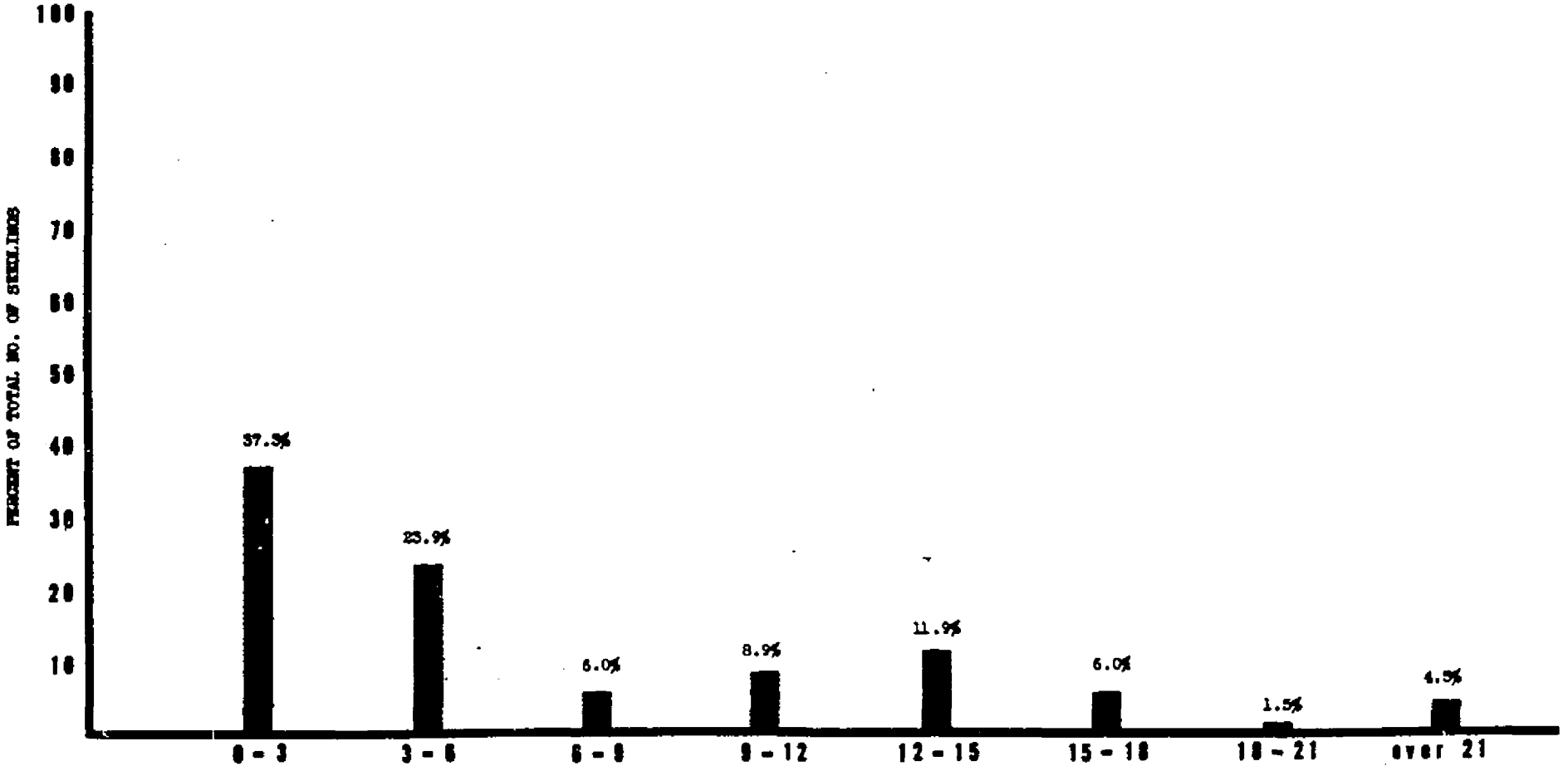

FIGURE 4 : CLASSES IN MG/100 GMS TOTAL CAROTENOID PIGMENTS
FEMALE PARENT - 2 MG/100 GMS TOTAL CAROTENOID PIGMENTS
MALE PARENT - 16 MG/100 GMS TOTAL CAROTENOID PIGMENTS

FIGURE 3 : CLASSES IN MG/100 GMS TOTAL CAROTENOID PIGMENTS

(%)

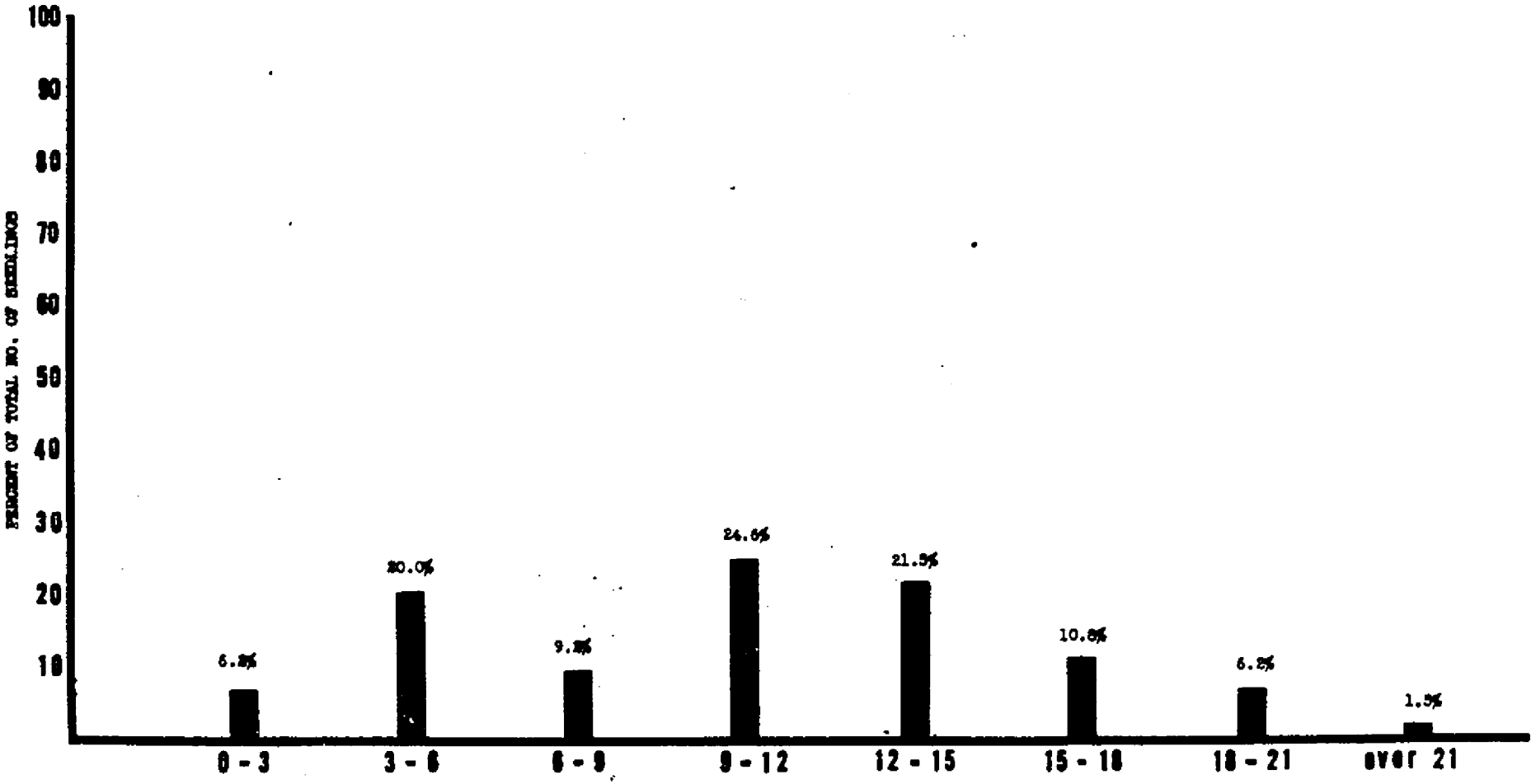

FIGURE 6 : CLASSES IN MG/100 GMS TOTAL CAROTENOID PIGMENTS

FEMALE PARENT - 6 MG/100 GMS TOTAL CAROTENOID PIGMENTS

MALE PARENT - 6 MG/100 GMS TOTAL CAROTENOID PIGMENTS

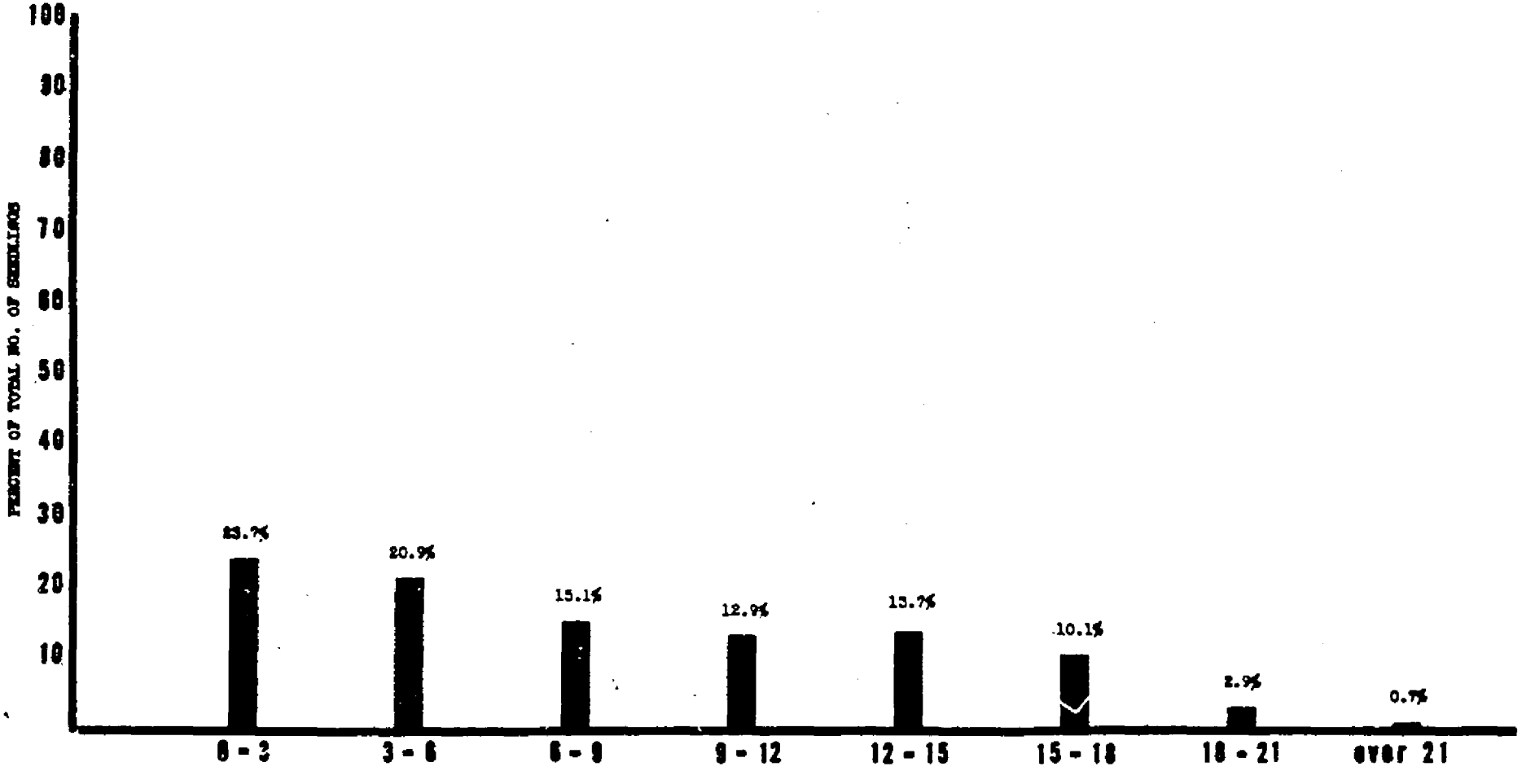

FIGURE 7: CLASSES IN MG/100 GMS TOTAL CAROTENOID PIGMENTS

FEMALE PARENT - 6 MG/100 GMS TOTAL CAROTENOID PIGMENTS

MALE PARENT - 12 MG/100 GMS TOTAL CAROTENOID PIGMENTS

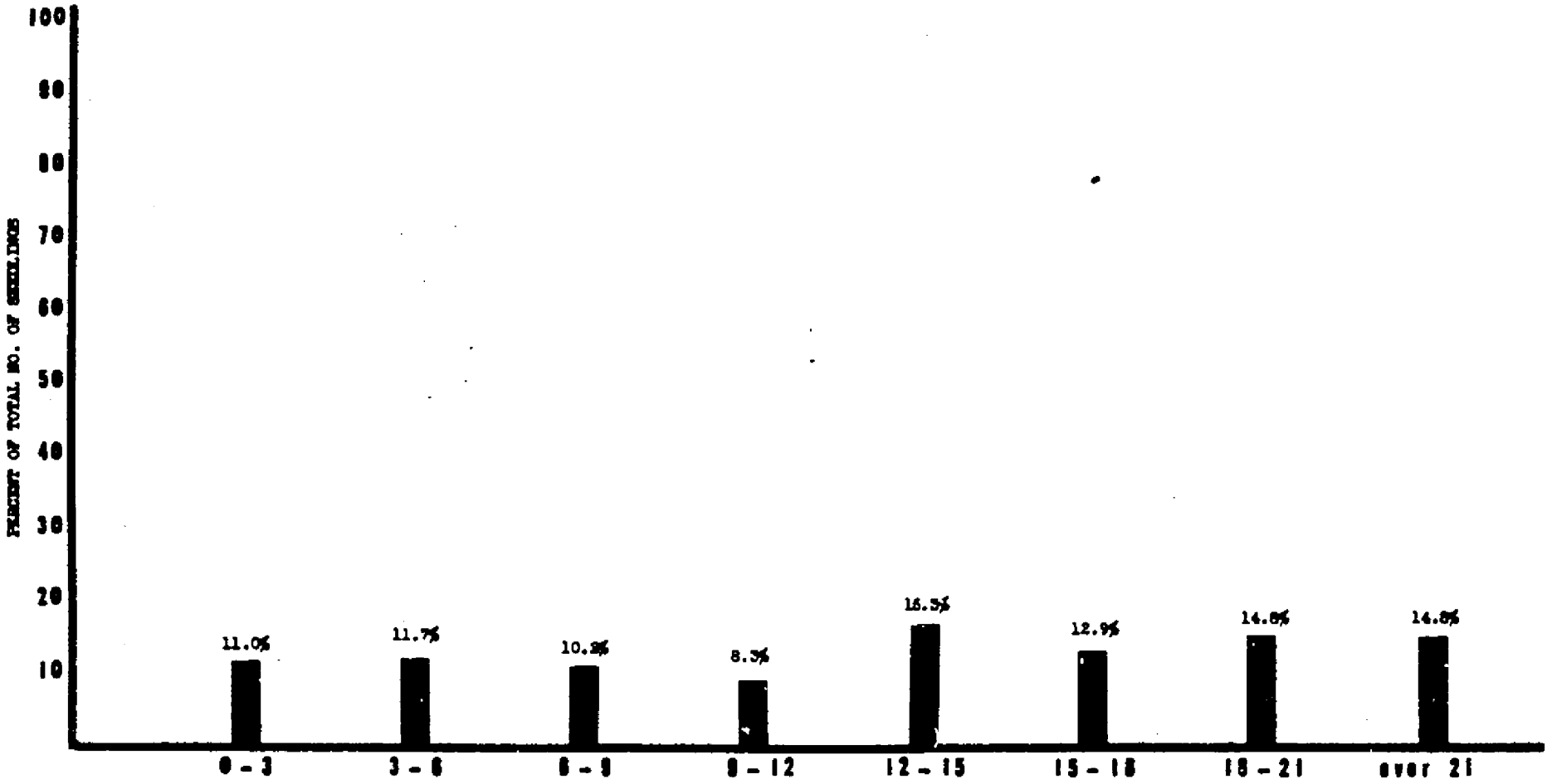

FIGURE: 8 CLASSES IN MG/100 GMS TOTAL CAROTENOID PIGMENTS

FEMALE PARENT - 6 MG/100 GMS TOTAL CAROTENOID PIGMENTS

MALE PARENT - 18 MG/100 GMS TOTAL CAROTENOID PIGMENTS

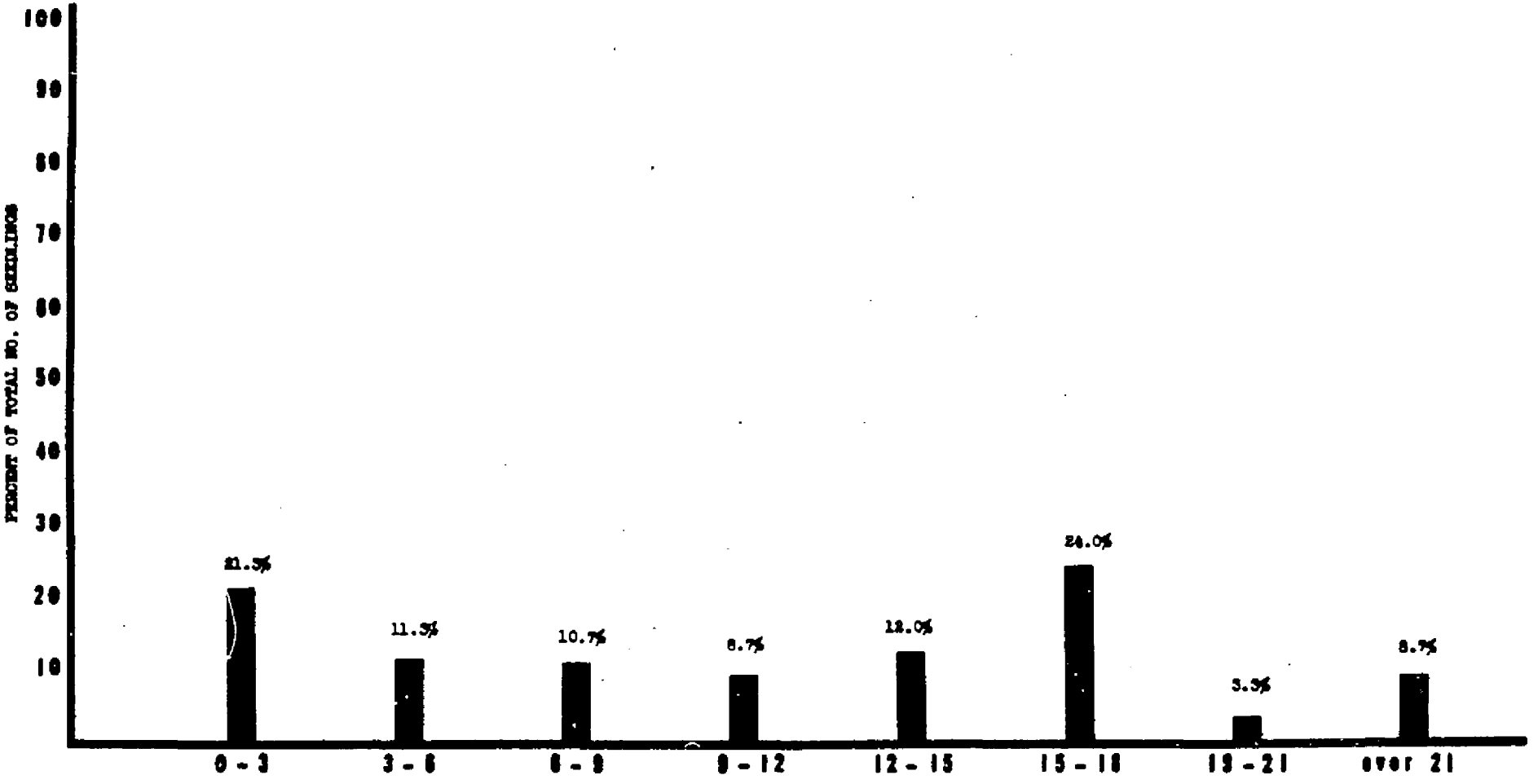

FIGURE 9 : CLASSES IN MG/100 GMS TOTAL CAROTENOID PIGMENTS

FEMALE PARENT - 18 MG/100 GMS TOTAL CAROTENOID PIGMENTS

MALE PARENT - 18 MG/100 GMS TOTAL CAROTENOID PIGMENTS

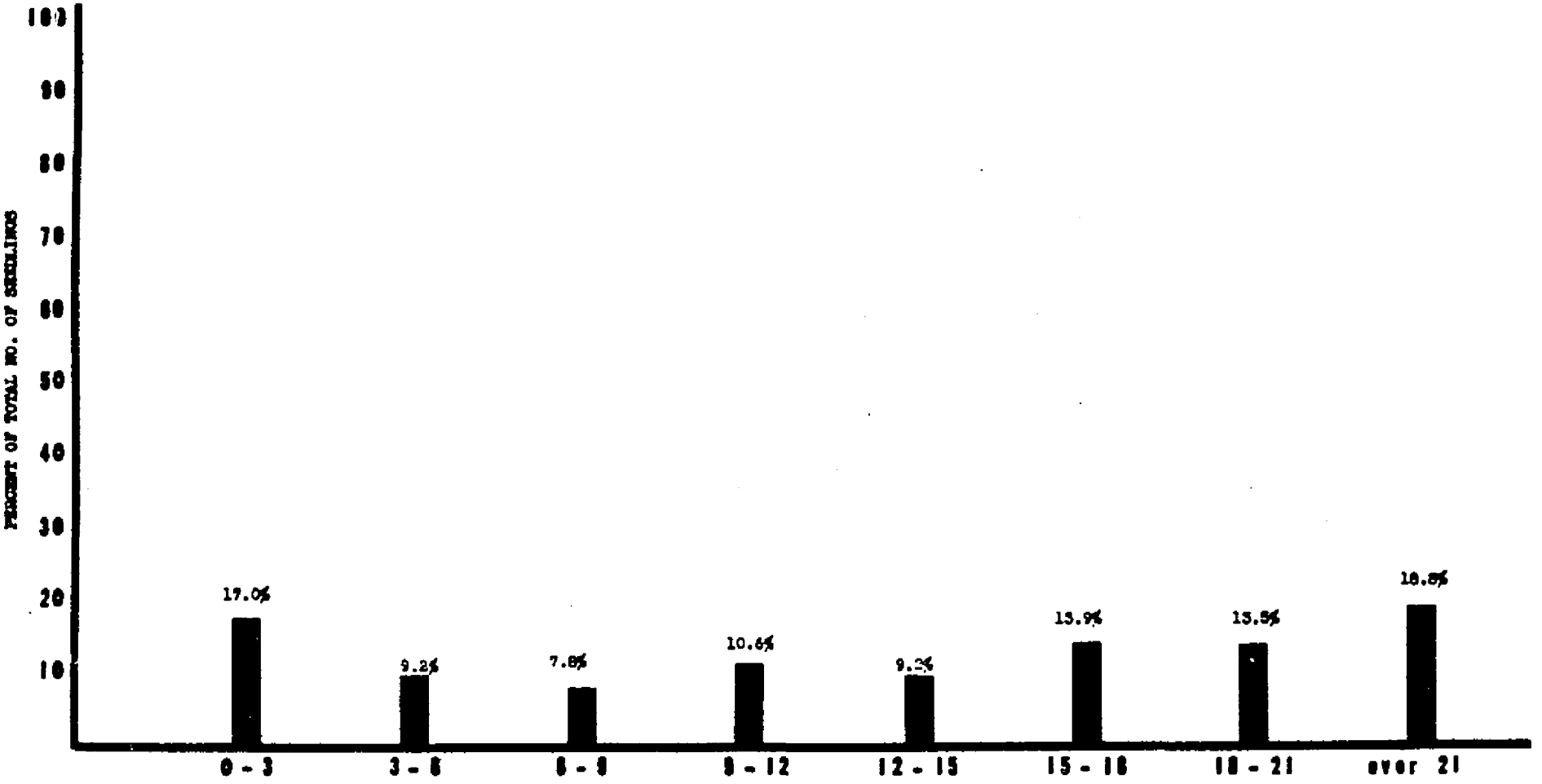

FIGURE 10 : CLASSES IN MG/100 GMS TOTAL CAROTENOID PIGMENTS

FEMALE PARENT - 12 MG/100 GMS TOTAL CAROTENOID PIGMENTS

MALE PARENT - 18 MG/100 GMS TOTAL CAROTENOID PIGMENTS

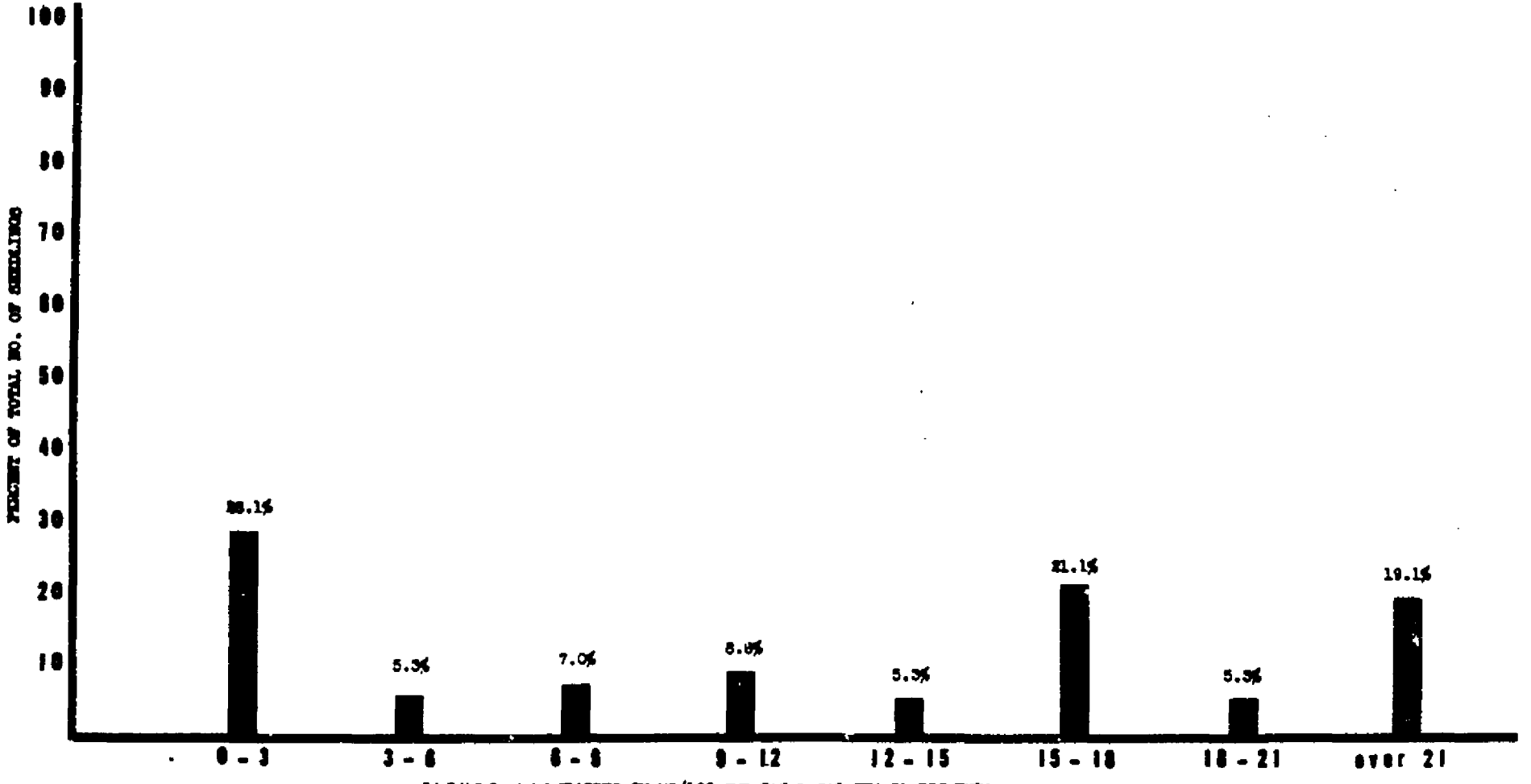

FIGURE 11: CLASSES IN MG/100 GMS TOTAL CAROTENOID PIGMENTS
18 (x)

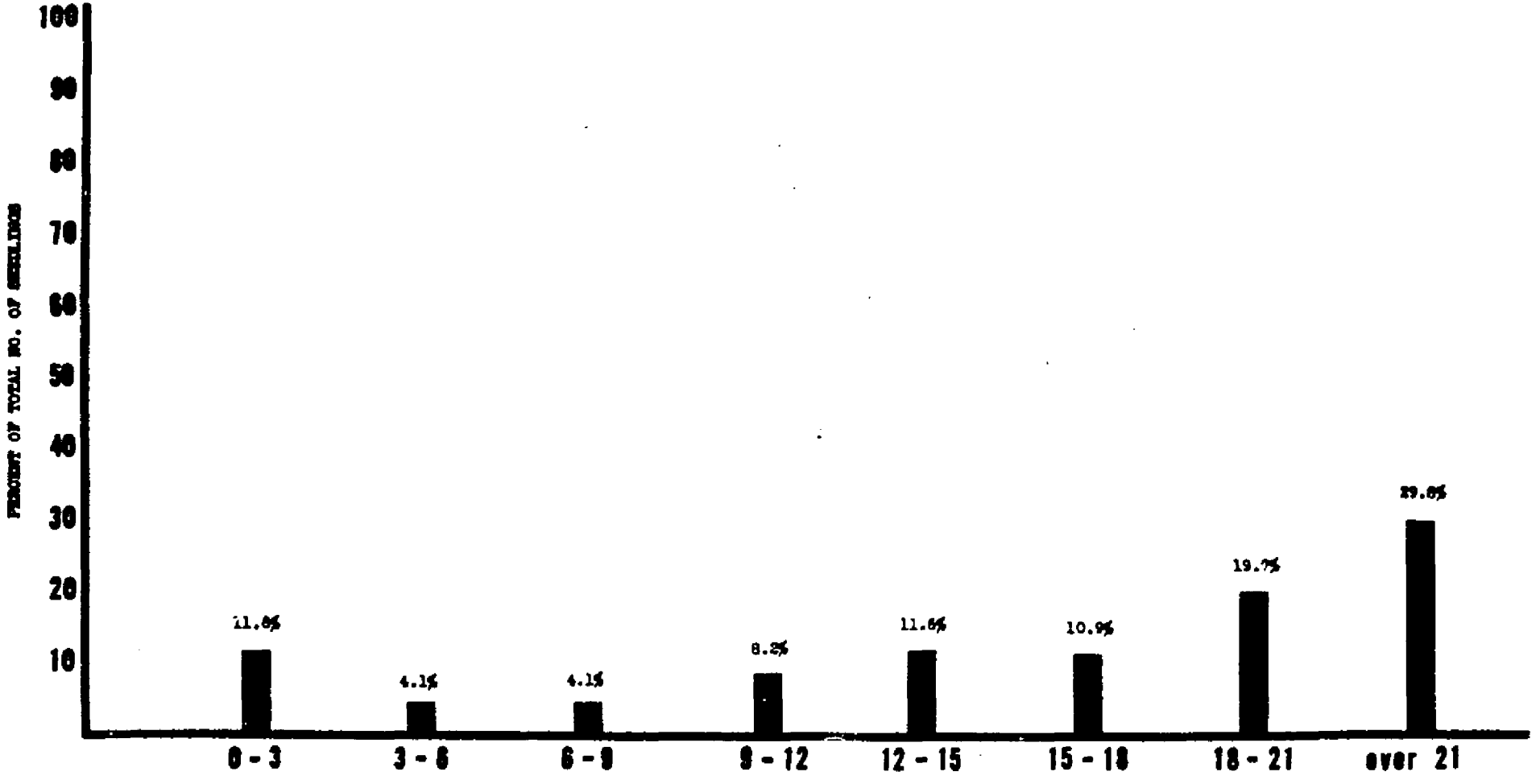

FIGURE 12: CLASSES IN MG/100 GMS TOTAL CAROTENOID PIGMENTS

FEMALE PARENT 18 MG/100 GMS TOTAL CAROTENOID PIGMENTS

MALE PARENT 18 MG/100 GMS TOTAL CAROTENOID PIGMENTS

The distribution of seedlings into various carotenoid classes resulting from a cross of a female parent containing 6 mg. of total carotenoid pigments/100 gm. roots on fresh weight basis and a male parent containing 18 mg./100 gm. fresh weight is shown in Figure 8. A large percentage of the seedlings had roots contained as much or more carotenoids than roots of the parent with the highest carotenoid content. A total of 78 out of 264 seedlings or 29.6 percent had roots with a total carotenoid content as high or higher than that of the parent having the highest carotenoid content. However, a total of 60 out of 264 seedlings or 22.7 percent had roots that were as low or lower in total carotenoid content than the lowest parent. The remaining seedlings had roots that varied in total pigments from 6 mg./100 gm. to 18 mg./100 gm. fresh weight. The mean total carotenoid content of the roots of the F_1 seedling population was 12.86 mg./100 gm. fresh weight.

When two parents with roots containing 18 mg. total carotenoid pigments/100 gm. fresh weight of roots were crossed, a total of 73 out of 147 seedlings or 49.5 percent of the seedlings had a pigment content of 18 mg./100 gm. of fresh root or higher, Figure 12. Although a fairly large number of the seedlings was in high carotenoid pigment classes, there were 11.6 percent that had 0 to 3 mg./100 gm. fresh weight. Also, there were 38.9 percent of the seedlings that were fairly high to intermediate in total carotenoid content. This indicates a transgressive segregation. The mean total carotenoid content of the roots of the F_1 seedling population was 15.80 mg./100 gm. fresh weight.

When a parent was selfed, even if the total carotenoid content of the roots was high, a fairly large number of seedlings had roots that were white or low in total pigments. When Kandee, which had roots with 6 mg. total carotenoid pigments/100 gm. was selfed, Figure 5, 65.9 percent of the F_1 seedlings had little or no total pigments. When Centennial, with 18 mg. total pigments/100 gm. was selfed, Figure 11, 28.1 percent of its F_1 seedlings had roots with little or no pigment. However, some seedlings had roots with a total carotenoid pigment content over that of Centennial. A total of 14 out of 57 seedlings or 24.4 percent of the seedlings had roots with a total pigment content over that of Centennial. The remaining 47.5 percent of the F_1 seedlings had roots that fell into the intermediate total pigment classes. A possible explanation for the large number of white flesh seedlings segregating from high total carotenoid parents is the epistatic action of two or more white genes over genes for orange flesh or the presence of an inhibitor gene. The character for orange flesh color (total carotenoid pigments) is controlled by several genes. These genes, possibly 6, are probably additive in effect.

Comparative Techniques in Total Carotenoid Determination

Several techniques were compared in determining the total pigment in the progenies of the seedlings studied. The Gardner Color Difference Meter was used to obtain the L, a_L and b_L values in the roots of each seedling. Also, these same seedlings were rated objectively with scores of 0 for no pigment to 5 for very high total carotenoid content. The roots

of each seedling were also analyzed quantitatively for the actual total carotenoid pigments.

Correlation coefficients were calculated between observed total carotenoid pigments and L, a_L, and b_L values (Table 4). It was found that a highly significant negative correlation coefficient of -.8885 existed between observed total carotenoid pigments and L value. A highly significant positive correlation coefficient of +.9118 existed between observed total carotenoid pigments and a_L value. The observed total carotenoid pigments and b_L value had a highly significant correlation coefficient of +.3234.

TABLE 4: Correlation Coefficients Between Total Carotenoid Pigments and Other Variables for Sweet Potato Progenies

Variables	Correlation Coefficients
Total Pigments[1] and L Values	-.8632**
Total Pigments and a_L Values	+.8455**
Total Pigments and b_L Values	+.2166**
Observed Total Pigments[2] and L Values	-.8885**
Observed Total Pigments and a_L Values	+.9118**
Observed Total Pigments and b_L Values	+.3234**
Observed Total Pigments and Total Pigments	+.7989**
L Values and a_L Values	-.9272**
L Values and b_L Values	-.2414**
a_L Values and b_L Values	+.2820**

**-Significant at the 1% level.
1-Determined by quantitative analysis.
2-Determined by visual scale.

The correlation coefficients were calculated between observed total caretenoid pigments and quantitative determination of total carotenoid pigments. It was found that this correlation coefficient of +.7929 was positive and highly significant (Table 4).

Similar correlation coefficients were obtained between quantitative total carotenoid pigment determinations and L, a_L, and b_L values as obtained with observed total caretenoid pigment determinations and L, a_L, and b_L values. From these studies, it was found that the L and a_L values are more reliable estimates of the total carotenoid pigments than the b_L values. A highly significant negative correlation coefficient of -.9272 existed between the L and a_L values. However, a correlation coefficient of -.2414 existed between L and b_L values. These data suggest that total carotenoid content of sweet potato roots can be predicted by visual observation with as high a degree of accuracy as it can be with a tristimulus colorimeter.

Inheritance of Skin Color

The data showing the number of seedlings in each skin color class from different parental combinations are given in Table 5. Also, the percentage of the total number of seedlings in each skin color class of the same parental combination is given in Table 6.

When a female parent with roots of a white skin color was crossed with a male parent with roots of a copper skin color, 48 seedlings out of 357 or 13.4 percent of the seedlings had roots of white skin color (Figure 13). A total of 81 out of 357 or 22.7 percent of the seedlings had roots of a copper skin color. A large percentage of the seedlings

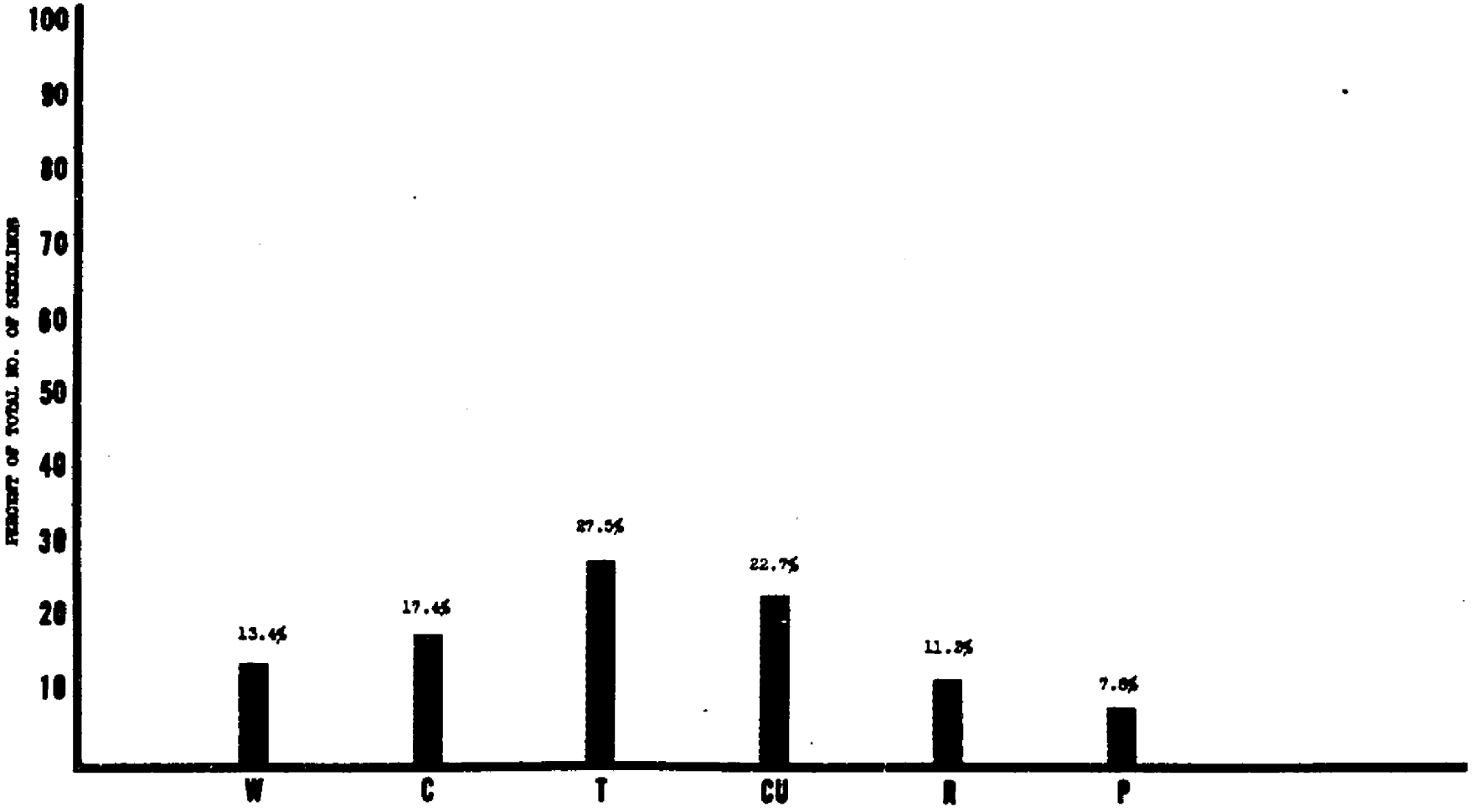

FIGURE 13: SKIN COLOR CLASSES
FEMALE PARENT - WHITE
MALE PARENT - CU

TABLE 5: Frequency Distribution of F_1 Sweet Potato Seedlings into Different Skin Color Classes

Parental Cross*	Number of F_1 Seedlings	Number of F_1 Seedlings in Each Skin Color					
		White	Cream	Tan	Cooper	Rose	Purple
Copper (X)	57	0	3	13	25	4	12
White X copper	357	48	62	98	81	40	28
Cream X copper	166	2	12	55	62	21	14
Cream X Rose	27	0	0	9	8	3	7
Cream X purple	32	0	0	5	7	7	13
Copper X Copper	373	1	29	94	169	49	31
Copper X Rose	443	1	16	90	228	71	37
Copper X Purple	18	0	0	3	1	8	6
Rose X Rose	58	0	3	10	19	15	11
Rose X Purple	21	0	0	0	1	2	18

*Parental cross represents female and male parents, respectively.

TABLE 6: Percentage of Total F_1 Sweet Potato Seedlings into Different Skin Color Classes

Parental Cross*	Number of F_1 Seedlings	Percent of F_1 Seedlings in Each Skin Color					
		White	Cream	Tan	Copper	Rose	Purple
Copper (X)	57	0.0	5.3	22.8	43.9	7.0	21.0
White X Copper	357	13.4	17.4	27.5	22.7	11.2	7.8
Cream X Copper	166	1.2	7.2	33.1	37.3	12.7	8.5
Cream X Rose	27	0.0	0.0	33.3	29.6	11.2	25.9
Cream X Purple	32	0.0	0.0	15.6	21.9	21.9	40.6
Copper X Copper	373	0.3	7.8	25.2	45.3	13.1	8.3
Copper X Rose	443	0.2	3.6	20.3	51.5	16.0	8.4
Copper X Purple	18	0.0	0.0	16.7	5.6	44.4	33.3
Rose X Rose	58	0.0	5.1	17.2	32.8	25.9	19.0
Rose X Purple	21	0.0	0.0	0.0	4.8	9.5	85.7

*Parental cross represents female and male parents, respectively.

fell in the cream and tan classes. For example, out of 357 F_1 seedlings, 160 seedlings or 44.9 percent had either a cream or tan skin. In addition, some seedlings segregated for rose or purple skin color which is darker than that of either parent.

Results in Figure 14 show the percentage of the total number of seedlings in each skin color class when a cross was made between a female parent having roots with a cream skin color and a male parent with a copper skin color. A total of 55 seedlings out of 166 or 23.1 percent of the total number of seedlings produced roots with tan skin color. The largest percentage of the seedlings fell into the copper skin class. A total of 62 out of 166 seedlings or 37.3 percent of the seedlings had roots with copper skin. Some progenies also segregated for rose or purple skin color which was darker than either of the two parents.

The results from a cross between two parents with copper skin colored roots are given in Figure 16. From a total of 373 seedlings, 169 seedlings or 45.3 percent had roots of copper skin color. Similar results were obtained when a parent with copper skin color was selfed. Forty-three and nine-tenths percent of the total number of seedlings had copper skin roots (Figure 15). However, a large number of seedlings with roots of a purple skin color segregated. When a parent with roots of a copper skin color was selfed, 21.0 percent of the seedlings had purple skin as compared to 8.3 percent from a cross between two parents with roots of a copper skin color.

Female parents with roots of a copper skin color were crossed with male parents with roots of a rose color. From a total of 443

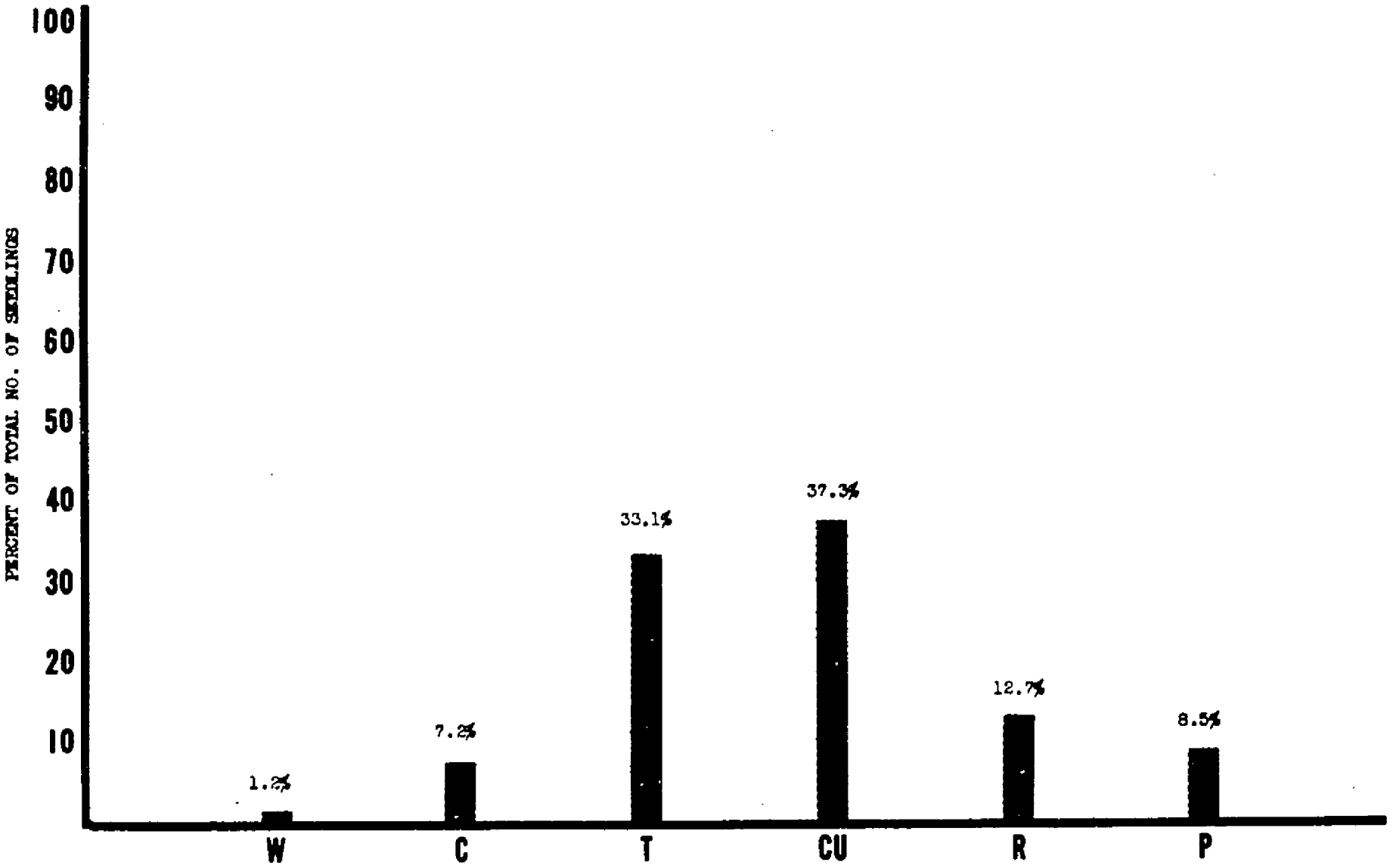

FIGURE 14 : SKIN COLOR CLASSES

FEMALE PARENT - CREAM

MALE PARENT - CU

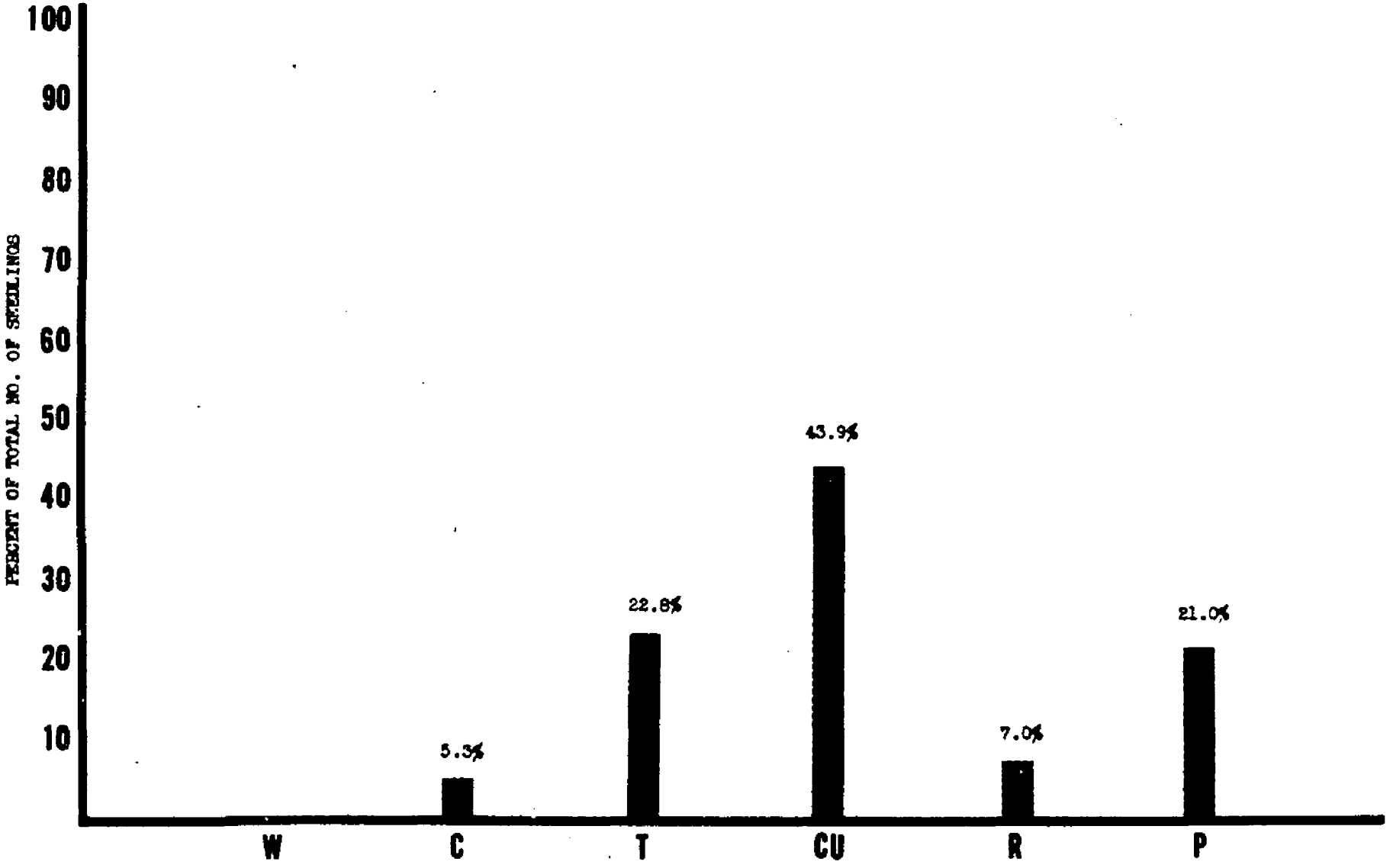

FIGURE 15 : SKIN COLOR CLASSES

CU (x)

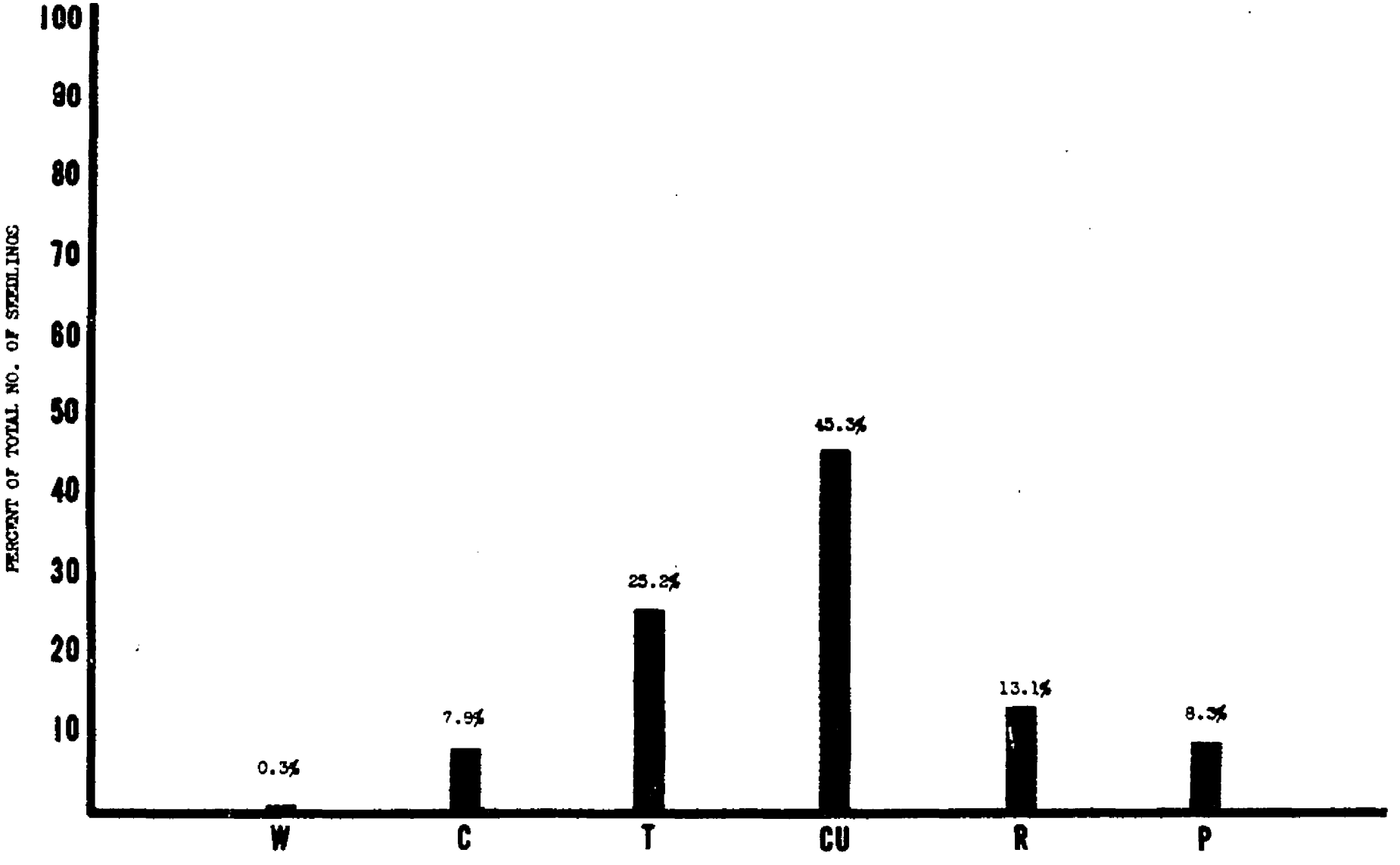

FIGURE 16: SKIN COLOR CLASSES

FEMALE PARENT - CU

MALE PARENT - CU

seedlings, 228 or 51.5 percent had roots with copper skin color, 20.3 percent had roots with tan skin color, 16.0 percent had roots with rose skin color, and 8.4 percent had roots with purple skin color.

The darker the skin color of roots of the parents involved in a cross, the larger was the percentage of the F_1 seedlings with rose or purple skin colored roots. In a cross involving a female parent producing roots with rose skin color and a male parent with purple skin colored roots, 85.7 percent of the seedlings segregated for purple skin. These data suggest that the character for skin color in sweet potatoes is qunatitative in nature and controlled by several genes. This indicates the presence of complementary genes (Cream and Red) and possibly the presence of a basic gene (Dark) for color.

Correlation coefficients were calculated between total carotenoid pigments and skin color, Table 7. A highly significant positive correlation coefficient of +.2186 existed. In general, the

TABLE 7: Correlation Between Skin Color and Other Variables for Sweet Potato Progenies

Variables	Correlation Coefficients
Skin Color and Total Pigments[1]	+.2186**
Skin Color and Observed Total Pigments[2]	+.2773**
Skin Color and L Values[3]	-.2758**
Skin Color and a_L Values[3]	+.2750**
Skin Color and b_L Values[3]	-.0935*

*-Significant at the 5% level.
**-Significant at the 1% level.
1-Determined by quantitative analysis.
2-Determined by visual scale.
3-Gardner Color Difference Meter values for total carotenoid pigments.

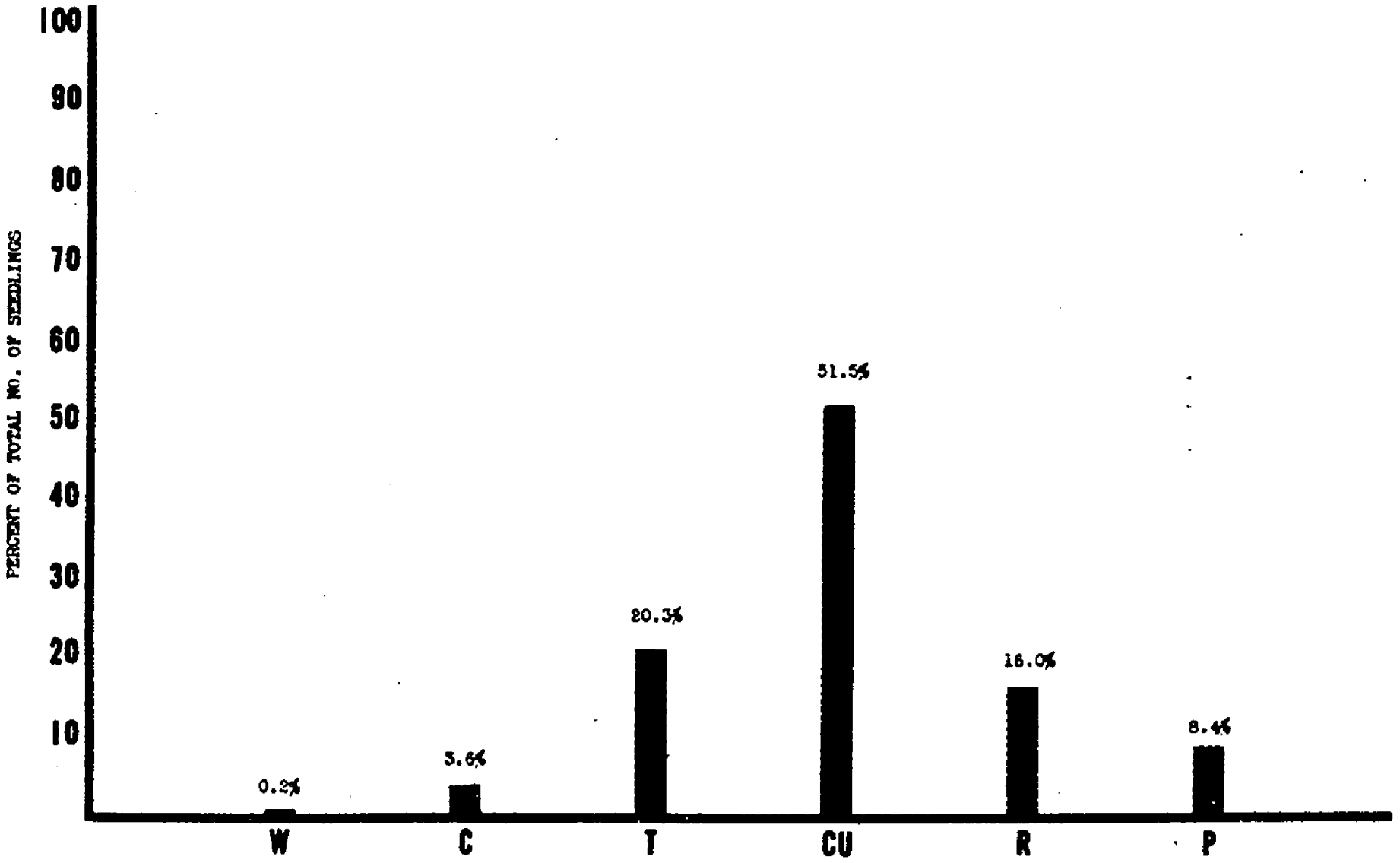

FIGURE 17 : SKIN COLOR CLASSES

FEMALE PARENT - CU

MALE PARENT - ROSY

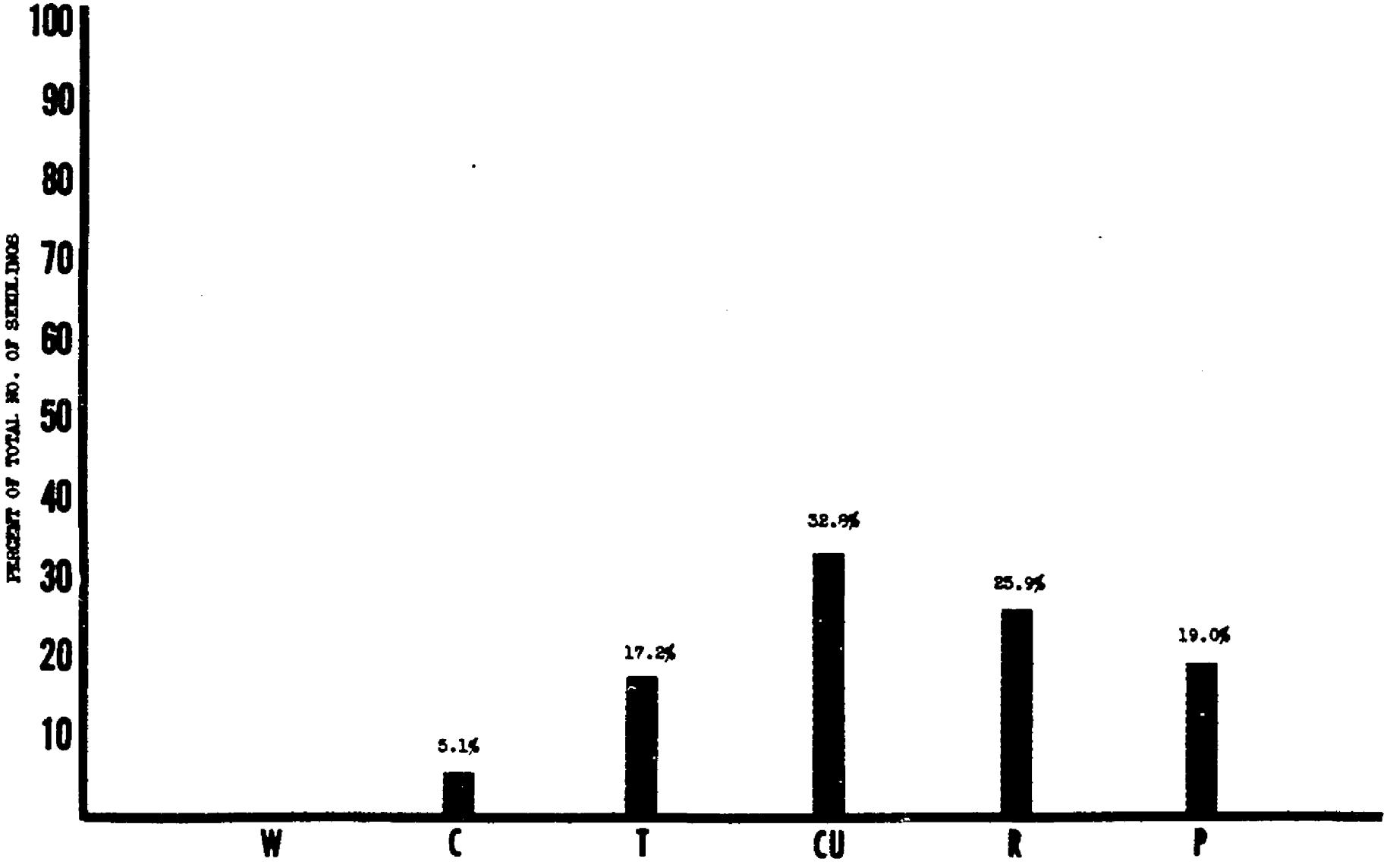

FIGURE 18: SKIN COLOR CLASSES
FEMALE PARENT - ROSE
MALE PARENT - ROSE

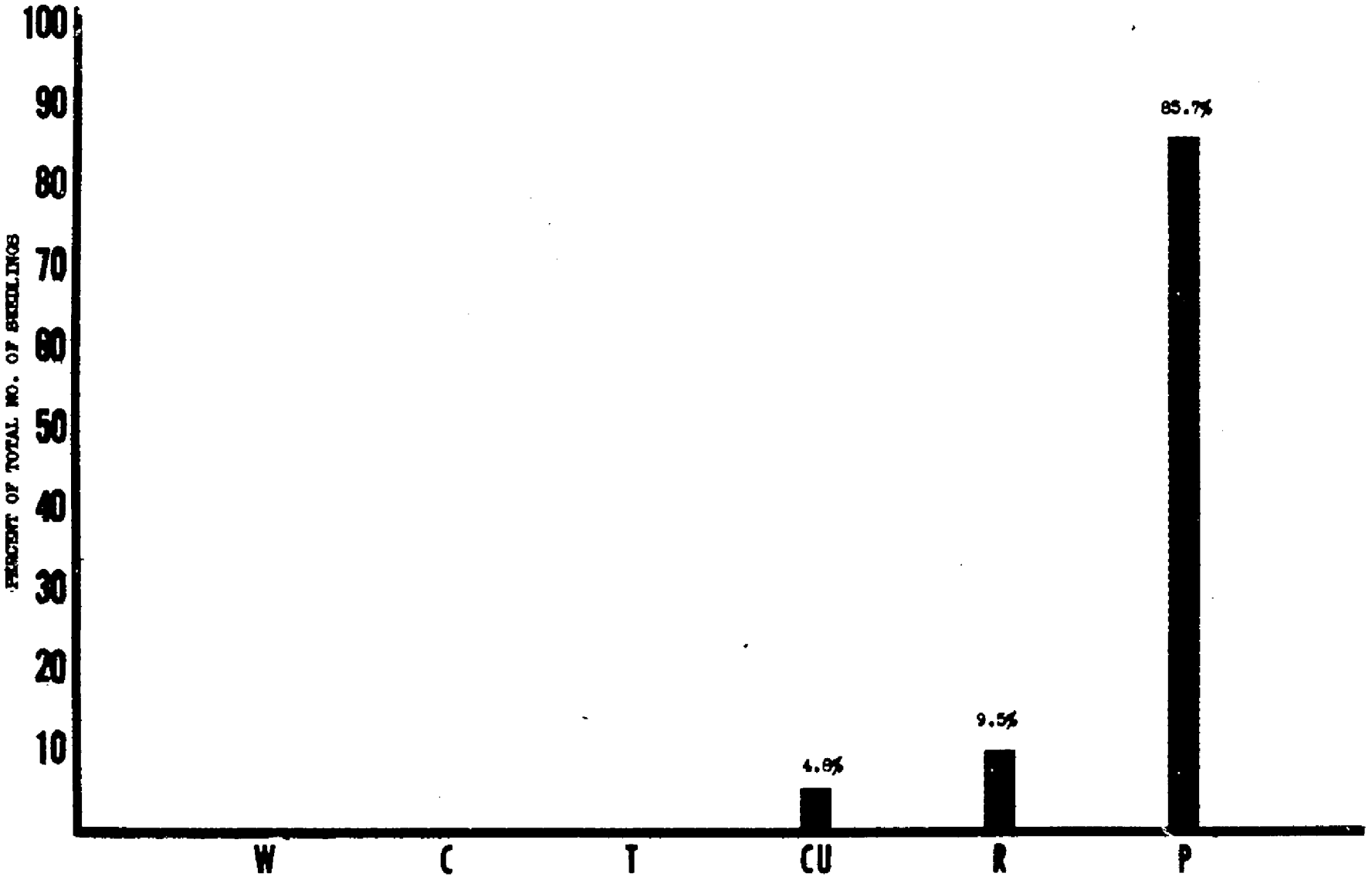

FIGURE 19: SKIN COLOR CLASSES
FEMALE PARENT - ROSE
MALE PARENT - PURPLE

seedlings with a dark skin color were higher in total carotenoid pigments. This indicated a possible linkage between pigmented skin color of roots of seedlings and total carotenoid pigments.

Correlation coefficients between skin color of roots and L and a_L values were all positive and highly significant (Table 7). The correlation coefficient between skin color and b_L values for total carotenoid pigments was negative and significant at the 5% level (Table 7).

Inheritance of Dry Matter

The data showing the segregation of different parental crosses and selfs analyzing varying percentages of dry matter are given in Tables 8 and 9, and Figures 20 through 31. In most cases, transgressive segregation occurred as there were seedlings in each progeny that were lower in dry matter than either parent. In most cases the mean percent dry matter of the progeny was equal to the mean of the two parents.

The majority of the breeding parents used were fairly high in dry matter. When Centennial, with 20 percent dry matter was selfed, 50 percent of the seedlings obtained had a dry matter content as high or higher than the parent. Twenty-six and eight-tenths percent of the seedlings were low to very low in dry matter and 16.1 percent were intermediate. When breeding parent Kandee with 28 percent dry matter was selfed, the results were similar to that obtained with Centennial selfed in the high dry matter class. However, Kandee produced fewer seedlings in the lower dry matter class and more in the intermediate class.

TABLE 8: Frequency Distribution of F_1 Sweet Potato Seedlings into Different Dry Matter Classes

Parental Cross or Self and Percent Dry Matter	Total Number of F_1 Seedlings	Number of F_1 Seedlings in Each Dry Matter Class						Mean Percent Dry Matter
		20-23%	23-26%	26-29%	29-32%	32-35%	Over 35%	
Kandee (X) (28% (X))	35	1	2	8	8	11	5	30.80
Centennial (X) (29% (X))	56	7	8	9	15	13	4	29.37
Centennial X L1-80 (29% X 29%)	62	3	11	18	11	10	9	29.42
Centennial X L3-80 (29% X 30%)	80	3	5	22	18	18	14	31.89
L1-80 X L3-80 (29% X 30%)	75	4	6	14	18	17	16	31.07
Centennial X L21 (29% X 32%)	62	1	5	16	17	15	8	30.63
P.I.213321 X L1-80 (30% X 29%)	195	1	4	40	76	59	15	31.04
P.I.213321 X L21 (30% X 32%)	129	3	9	26	52	26	13	31.39
L130 X L1-80 (31% X 29%)	107	6	11	14	31	21	24	31.14
L3-7 X L138 (36% X 25%)	35	1	1	8	11	9	5	31.46
L3-7 X L1-80 (36% X 29%)	60	4	5	13	19	10	9	30.43
L3-7 X L3-80 (36% X 30%)	80	1	2	12	18	22	25	33.27

TABLE 9: Percentage of F_1 Sweet Potato Seedlings into Different Dry Matter Classes

Parental Cross or Self and Percent Dry Matter	Total Number of F_1 Seedlings	Percent of F_1 Seedlings in Each Dry Matter Class					
		20-23%	23-26%	26-29%	29-32%	32-35%	Over 35%
Kandee (X) (28% (X))	35	2.8	5.7	22.8	22.8	31.5	14.4
Centennial (X) (29% (X))	56	12.5	14.3	16.1	26.8	23.2	7.1
Centennial X L1-80 (29% X 29%)	62	4.8	17.7	29.0	17.7	16.1	14.7
Centennial X L3-80 (29% X 30%)	80	3.7	6.3	27.5	22.5	22.5	17.5
L1-80 X L3-80 (29% X 30%)	75	5.3	8.0	18.6	24.0	22.7	21.4
Centennial X L21 (29% X 32%)	62	1.6	8.1	25.8	27.4	24.2	12.9
P.I.213321 X L1-80 (30% X 29%)	195	0.5	2.0	20.5	38.9	30.3	7.8
P.I.213321 X L21 (30% X 32%)	129	2.3	6.9	20.1	40.3	20.1	10.3
L130 X L1-80 (31% X 29%)	107	5.6	10.3	13.1	28.9	19.6	22.5
L3-7 X L138 (36% X 25%)	35	2.8	2.8	22.8	31.4	25.8	14.4
L3-7 X L1-80 (36% X 29%)	60	6.7	8.3	21.6	31.7	16.6	15.1
L3-7 X L3-80 (36% X 30%)	80	1.3	2.5	15.0	22.5	27.5	31.2

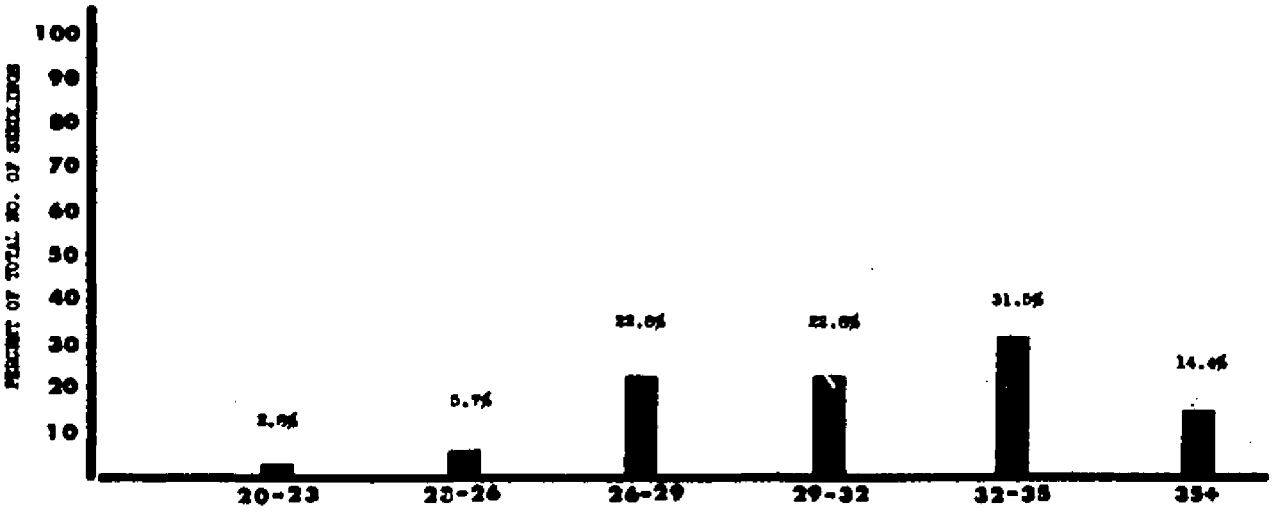

FIGURE 20: CLASSES IN PERCENTAGE DRY MATTER
RANGER (x) (80% (x))

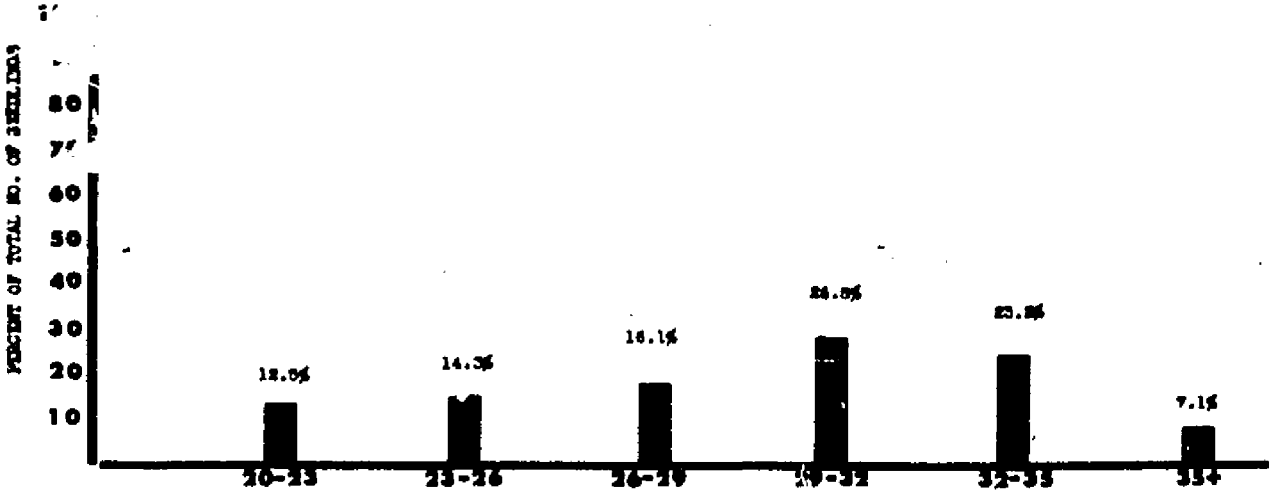

FIGURE 21: CLASSES IN PERCENTAGE DRY MATTER
CENTENNIAL (x) (80% (x))

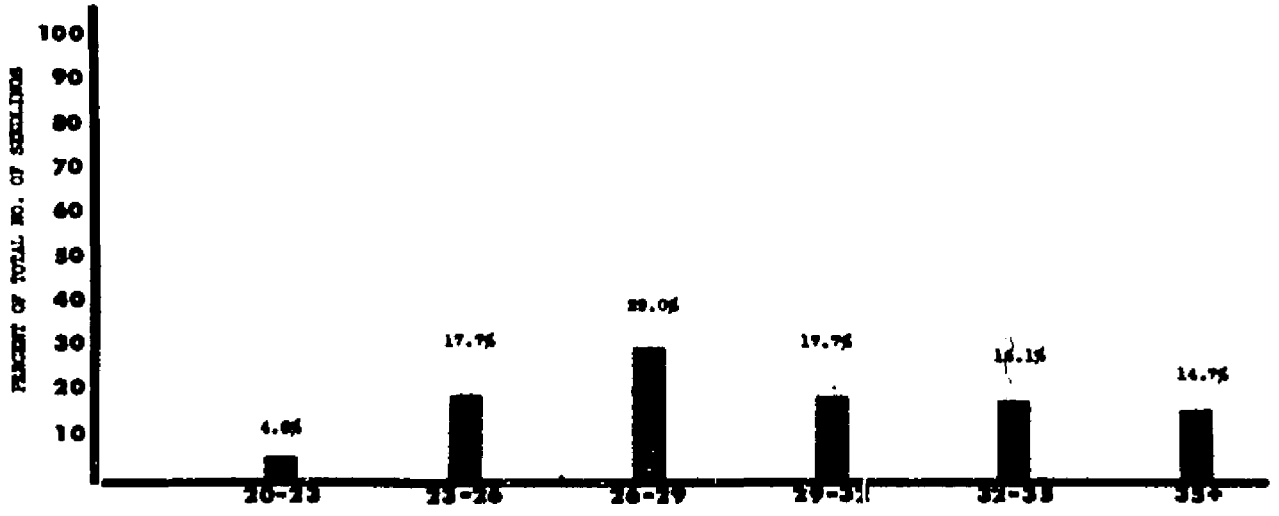

FIGURE 22: CLASSES IN PERCENTAGE DRY MATTER
FEMALE PARENT - CENTENNIAL MALE PARENT - L1-80 (99% x 29%)

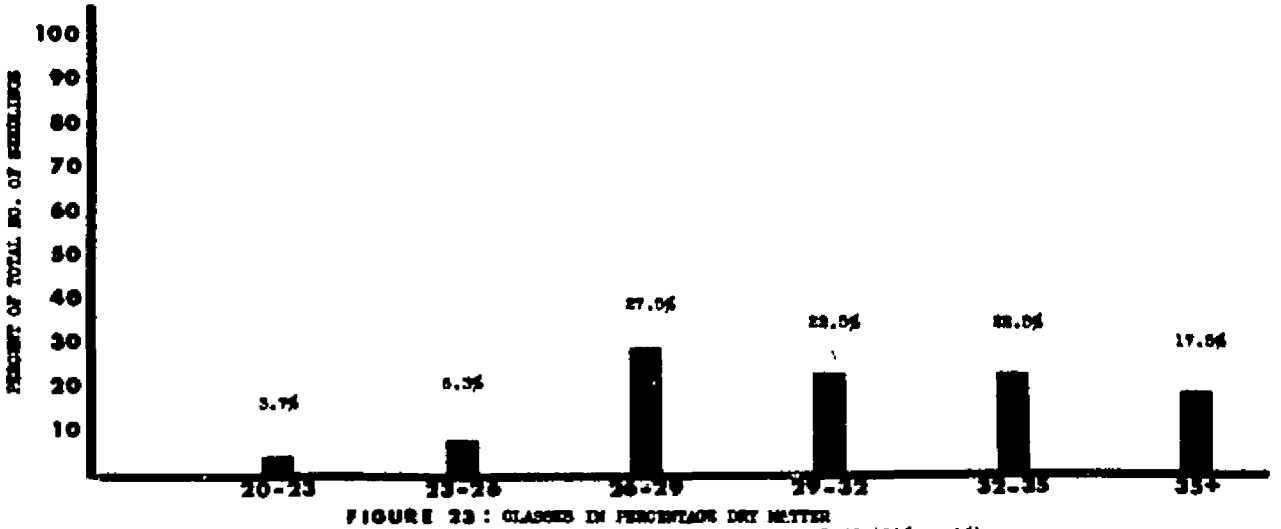

FIGURE 23 : CLASSES IN PERCENTAGE DRY MATTER
FEMALE PARENT - CENTENNIAL MALE PARENT - L3-60 (89% x 50%)

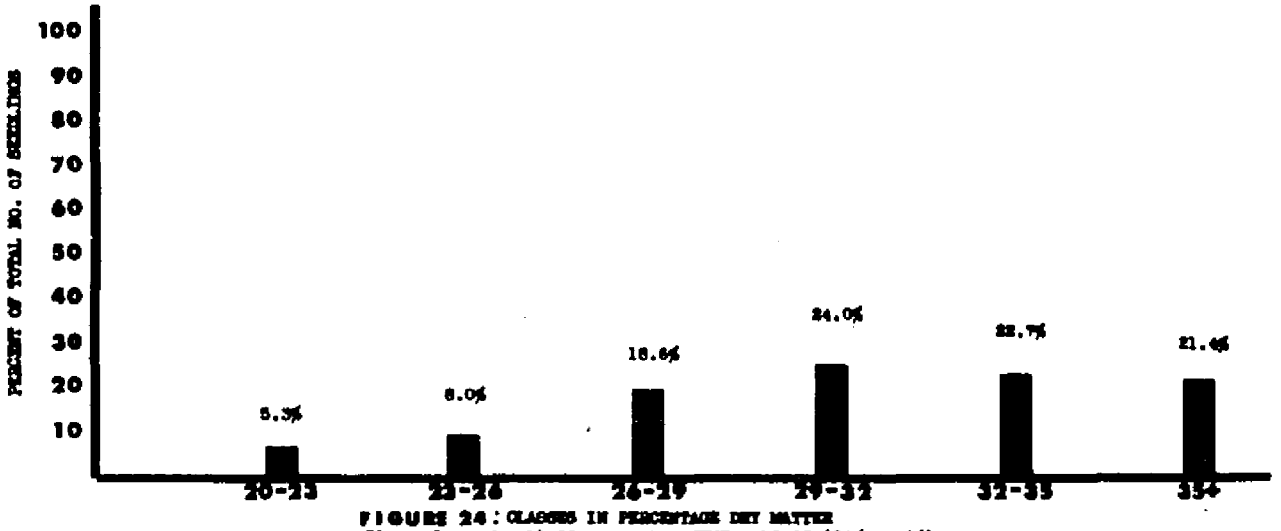

FIGURE 24 : CLASSES IN PERCENTAGE DRY MATTER
FEMALE PARENT - L1-60 MALE PARENT - L3-60 (89% x 50%)

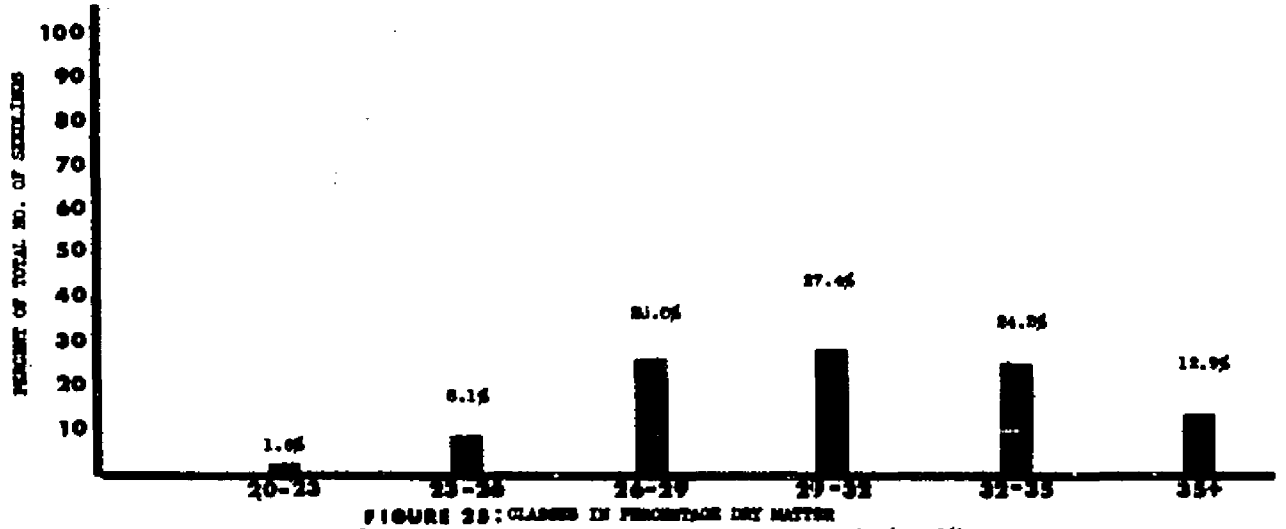

FIGURE 25 : CLASSES IN PERCENTAGE DRY MATTER
FEMALE PARENT - CENTENNIAL MALE PARENT - L81 (89% x 33%)

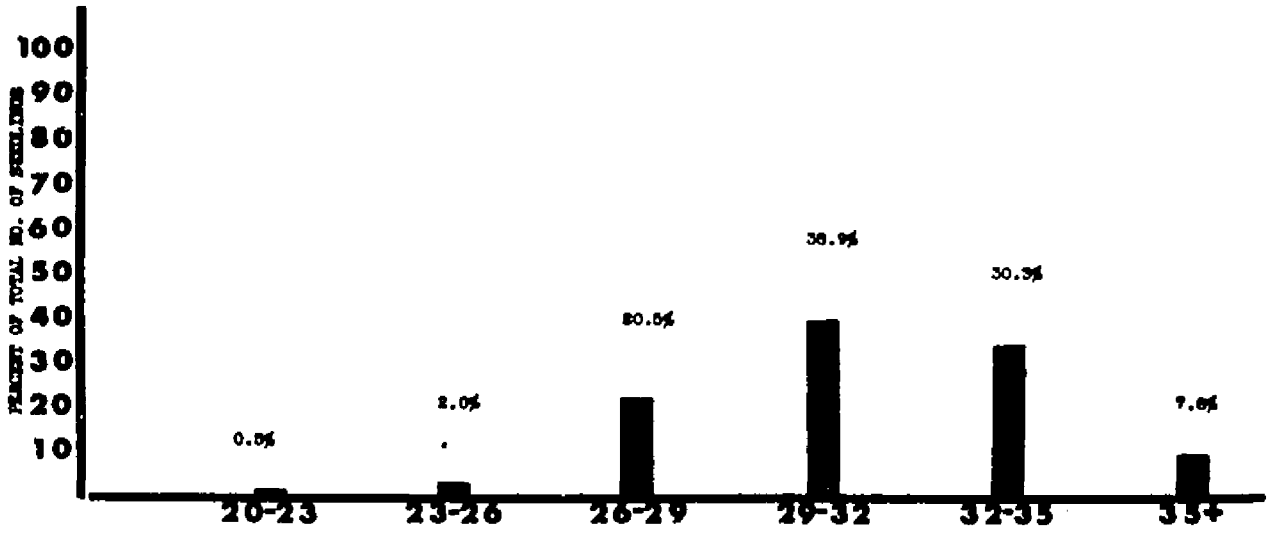

FIGURE 26: CLASSES IN PERCENTAGE DRY MATTER
FEMALE PARENT - P.I. 213521 B MALE PARENT - L1-80 (30 x 29)

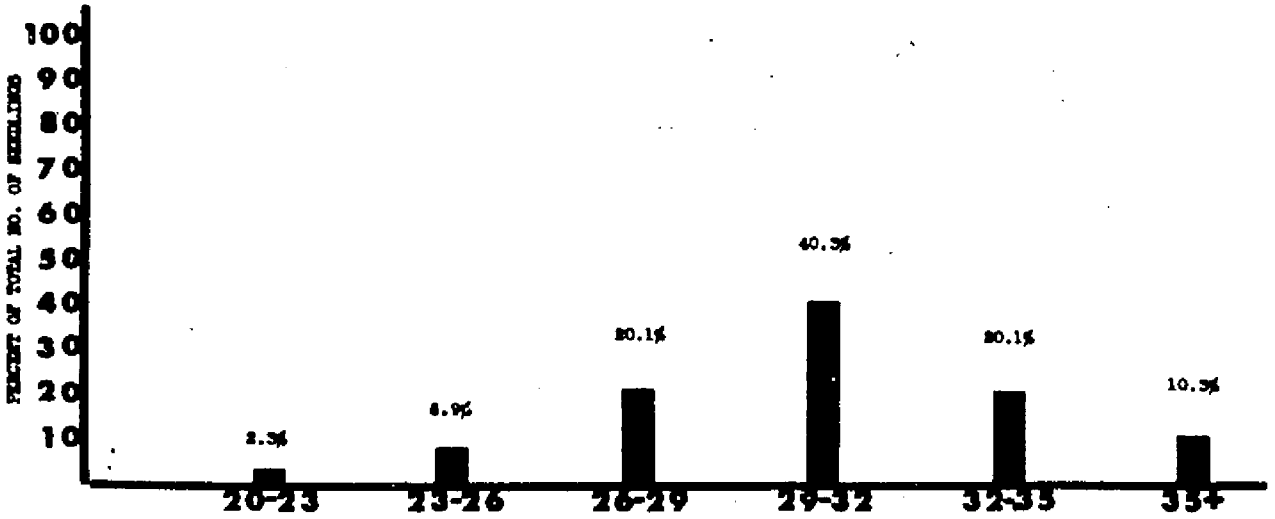

FIGURE 27: CLASSES IN PERCENTAGE DRY MATTER
FEMALE PARENT - P.I. 213541 B MALE PARENT - L81 (30 x 58)

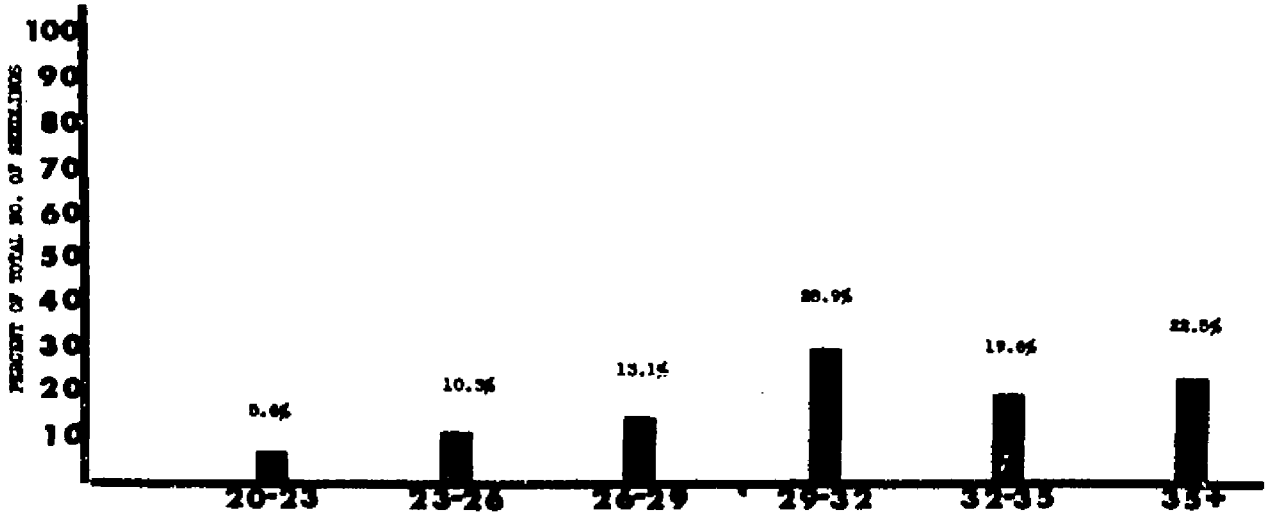

FIGURE 28: CLASSES IN PERCENTAGE DRY MATTER
FEMALE PARENT - L130 MALE PARENT - L1-80 (31 x 29)

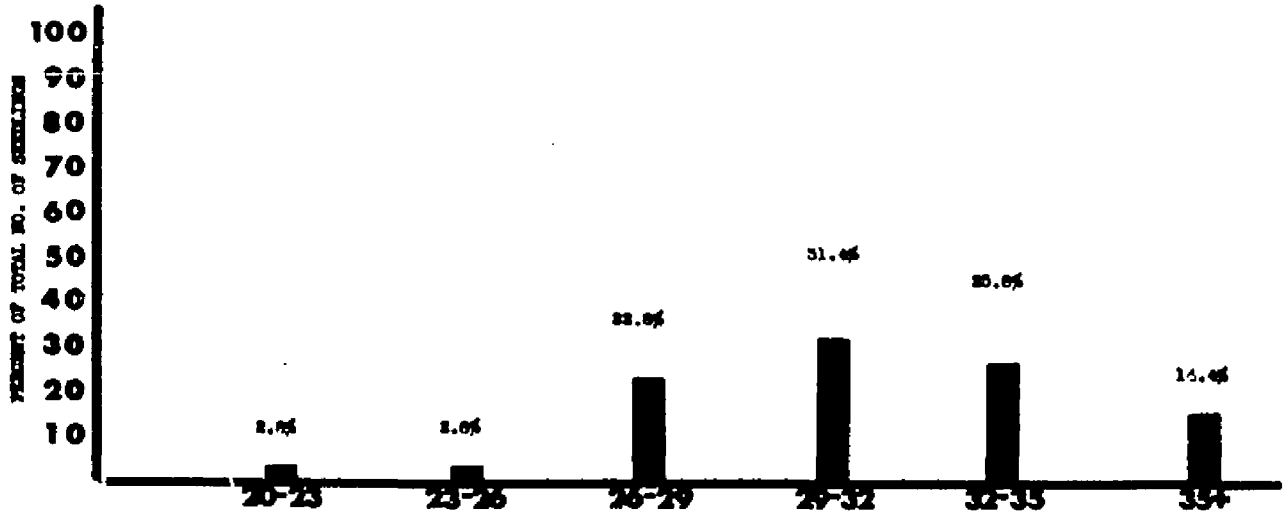

FIGURE 29 : CLASSES IN PERCENTAGE DRY MATTER
FEMALE PARENT - LS-7 MALE PARENT - L1-80 (36 x 35)

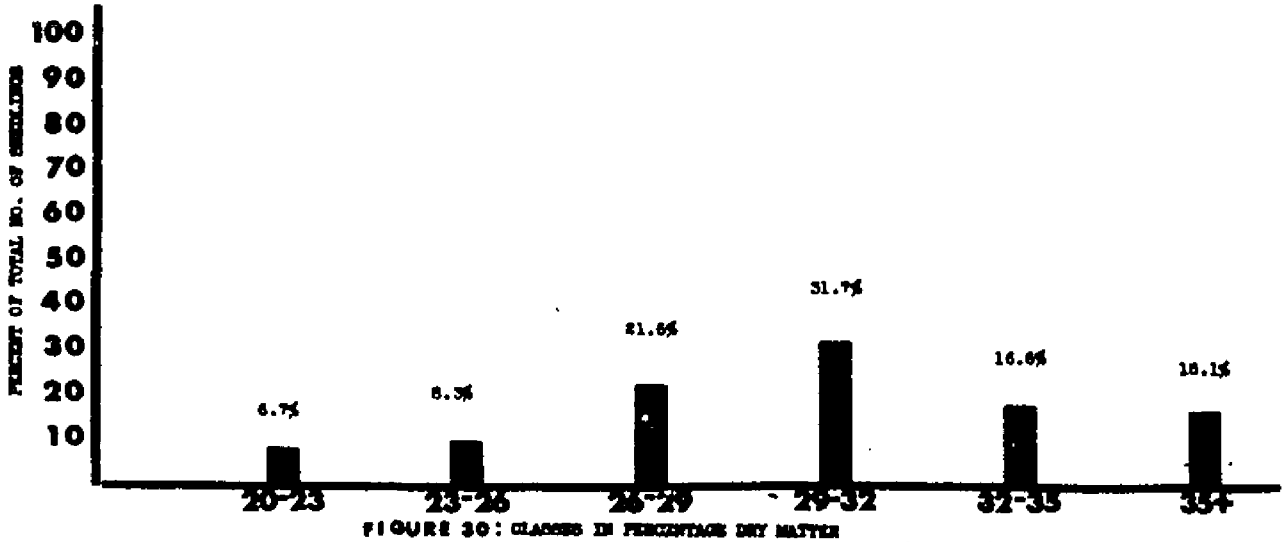

FIGURE 30 : CLASSES IN PERCENTAGE DRY MATTER
FEMALE PARENT - LS-7 MALE PARENT - L1-80 (36 x 29)

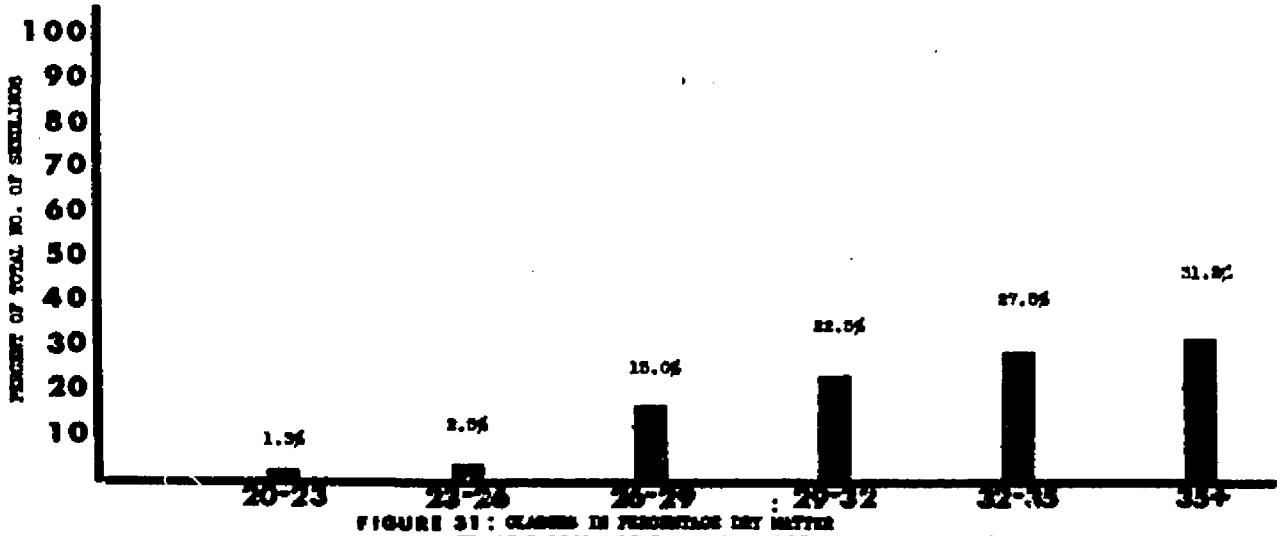

FIGURE 31 : CLASSES IN PERCENTAGE DRY MATTER
FEMALE PARENT - LS-7 MALE PARENT - LS-80 (36 x 30)

Correlation coefficients were calculated between percentage dry matter and total carotenoid pigments, Table 10. A highly significant negative correlation existed. This indicated that the roots of the seedlings of the progenies high in dry matter generally had a white flesh color or were very low in total carotenoid pigments.

A correlation coefficient between percentage dry matter of the roots and skin color was not significant.

TABLE 10: Correlation Coefficients Between Dry Matter and Other Variables for Sweet Potato Progenies

Variables	Correlation Coefficients
Dry Matter and Total Pigments[1]	-.2895**
Dry Matter and Observed Total Pigments[2]	-.3392**
Dry Matter and Skin Color	-.0260 n.s.
Dry Matter and L Values[3]	+.3183**
Dry Matter and a_L Values[3]	-.3410**
Dry Matter and b_L Values[3]	-.0915*

*-Significant at the 5% level.
**-Significant at the 1% level.
1-Determined by quantitative analysis.
2-Determined by visual scale.
3-Gardner Color Difference Meter values total carotenoid pigments.

Correlations Between Percentage Dry Matter and Total Carotenoid Pigments Within Each Progeny

Correlation coefficients were calculated between percentage dry matter and total carotenoid pigments on 14 progenies of different crosses and selfed parents. A highly significant negative correlation existed between these characters for all of the seedlings of all the progenies (Table 10). The varying degrees of association between these characters

among different progenies are indicated in Table 11. For example, in a cross between Centennial and L1-80 a highly significant negative correlation of -.5287 occurred between percentage dry matter and total carotenoid pigments. However, in a cross between L130 and L1-80 the correlation coefficient was positive but not significant. Since the same male parent was used in these crosses, this shows that Centennial has the desirable genotype for the transmission of genes for total carotenoid pigments while L130 has a tendency to produce more seedlings with a high dry matter content as well as fairly high total carotenoid pigment content.

TABLE 11: Correlation Coefficients Between Dry Matter and Total Carotenoid Pigments Within Each Sweet Potato Progeny

Female		Male	Correlation Coefficient
L3-77		(X)	-.2894 n.s.
Kandee		(X)	-.3513*
L1-80	X	L3-80	-.5387**
L3-7	X	L3-80	-.3781*
L3-7	X	L1-80	-.2212 n.s.
L3-7	X	L138	-.1890 n.s.
L3-77	X	L21	-.4806**
L3-77	X	L1-80	-.5287**
L3-77	X	L3-80	-.5326**
L130	X	L1-80	+.0554 n.s.
L131	X	L1-80	-.4528**
L131	X	L2-61	-.1264 n.s.
P.I.213321	X	L21	-.0031 n.s.
P.I.213321	X	L1-80	-.3680*

n.s. - not significant.
* - Significant at the 5% level.
** - Significant at the 1% level.

SUMMARY AND CONCLUSIONS

A study was made of the inheritance of skin and flesh color of the sweet potato roots and percentage dry matter using progenies from control crosses between several parents and from certain selfed selections. Techniques for evaluating seedlings for total carotenoid pigments in the roots also were compared.

When a seedling with roots of a white flesh color was crossed with a seedling low in carotenoid pigments (2 mg./100 gm. fresh weight), it was found that 98 percent of the seedlings had little or no carotenoid pigments in their roots. When the progenies from parents with roots of a white flesh color were crossed with a male parent high in total carotenoid pigments (18 mg./100 mg. fresh weight), 84.1 percent of the seedlings produced roots with little or no pigments.

In crosses between a parent with roots of 6 mg./100 gm. fresh weight, and one with 18 mg./100 gm., 29.6 percent of the seedlings produced roots with total carotenoid pigments as high as or higher than that of the parent with highest carotenoid pigment content. There were 11 percent of the seedlings with little or no carotenoid pigments and the rest of the seedlings were in the intermediate range (3 to 15 mg./100 gm. fresh weight).

In crosses between parents with roots containing carotenoid pigments of 18 mg./100 gm. fresh weight, 49.5 percent of the seedlings were

as high or higher than the parents. There were 11.6 percent of the seedlings with little or no carotenoid pigments.

When Centennial, with roots of total carotenoid pigments of 18 mg./100 gm. fresh weight, was self pollinated, 28.1 percent of the seedlings produced roots with little or no pigments. There were 24.4 percent of the seedlings with roots as high or higher in total carotenoid pigments than the parent.

The results above indicate that white flesh color is incompletely dominant over orange flesh color. A possible explanation for the large number of white flesh seedlings segregating from high total carotenoid parents is the epistatic action of two or more white genes over genes for orange flesh or the presence of an inhibitor gene. The character for orange flesh color is controlled by several genes. These genes, possibly 6, are probably additive in effect.

Correlation coefficients were obtained between quantitative total carotenoid pigment determinations and observed total carotenoid pigments using the visual scale of 0 to 5 for total pigment content. A highly significant positive correlation coefficient of +.7929 existed (Table 4), indicating that the visual scale gives a fairly reliable estimate of the total pigment content of sweet potato roots.

The L and a_L values on the Gardner Color Difference meter were also found to be reliable estimates of the total carotenoid pigments in sweet potato roots. A highly significant negative correlation coefficient of -.8632 existed between total carotenoid pigments and L values. A highly significant positive correlation coefficient of +.8455 existed between total pigments and a_L values. A weaker association existed between total

pigments and b_L values.

When a female parent with roots of a white skin color was crossed with a male parent with roots of a copper skin color, 13.4 percent of the seedlings had roots of white skin color and 22.7 percent had roots of a copper skin color. However, the largest percentage (44.9 percent) of the seedlings had roots in the cream or tan skin color classes. The remaining seedlings of the progeny had roots in the rose or purple skin color classes, which are darker than either of the two parents.

Of a total of 373 seedlings from a cross between two parents with copper skin colored roots, 45.3 percent had roots of copper skin color. However, a large percentage of seedlings produced roots of a purple skin color.

Female parents with roots of a copper skin color were crossed with male parents with roots of a rose color. Among the seedling progeny, 51.5 percent had roots with copper skin color, 20.3 percent had roots with tan skin color, 16.0 percent had roots with rose skin color, and 8.4 percent had roots with purple skin color.

The darker the skin color of roots of the parents involved in a cross, the larger was the percentage of the F_1 seedlings with rose or purple skin colored roots. The character for skin color in sweet potatoes is quantitative in nature and controlled by several genes. This indicates the presence of complementary genes (C and R) and possibly the presence of a basic gene (D) for color.

A highly significant positive correlation coefficient of +.2186 existed between skin color and total carotenoid pigments.

In most cases transgressive segregation occurred in F_1 sweet potato seedlings for inheritance of dry matter. There were seedlings in each progeny that were lower and some that were higher in dry matter than either parent. In most cases the mean percentage dry matter of the progeny was equal to the mean of the two parents.

A highly significant negative correlation coefficient existed between percentage dry matter and total carotenoid pigments. This indicated that the roots of the progeny seedlings high in dry matter generally had a white flesh color or were very low in total carotenoid pigments. The correlation coefficient between percentage dry matter and skin color of roots was not significant.

Varying degrees of association between percentage dry matter and total carotenoid pigments were found among different progenies. Breeding parent Centennial appears to have the genotype for the transmission of genes for high total carotenoid pigments and low dry matter, whereas, L130 has a tendency to produce seedlings with a high dry matter content and fairly high total carotenoid pigment content.

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AUTOBIOGRAPHY

Travis Paul Hernandez was born in Lafayette Parish on May 28, 1925. He attended grammar school and high school at Judice in Lafayette Parish. He graduated from high school in May, 1941.

He attended Louisiana State University from September, 1942 until July, 1943 at which time he enlisted in the United States Marine Corps. He remained in the Marine Corps until July, 1948, being honorably discharged with the rank of Staff Sargeant. He served one year in the Pacific Theater of war.

He re-entered Louisiana State University in September, 1948 and received a Bachelor of Science degree in June, 1951.

He entered the Graduate School, Louisiana State University in June, 1951, and was graduated with a Master of Science degree in Horticulture in August, 1952.

In February, 1953, he accepted a position in the Horticulture Department at the Sweet Potato Research Center, Chase, Louisiana. He worked there until February, 1961 at which time he re-entered the Graduate School at Louisiana State University. He is now a candidate for the degree of Doctor of Philosophy.

EXAMINATION AND THESIS REPORT

Candidate: Travis Paul Hernandez

Major Field: Horticulture/Agronomy

Title of Thesis: A Study of the Inheritance of Skin Color, Total Carotenoid Pigments, Dry Matter, and Techniques in Classifying These Characters in Ipomoea batatas.

Approved:

Julian C. Miller
Major Professor and Chairman

Max Goodrich
Dean of the Graduate School

EXAMINING COMMITTEE:

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Date of Examination:

May 9, 1963